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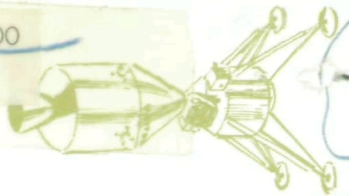
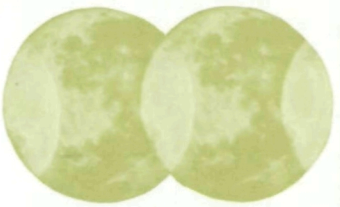
Volume 3



DEFINITION OF TELEMETRY EQUIPMENT FOR APOLLO PASSIVE LUNAR SCIENTIFIC EXPERIMENTS (TAPLE)



PREPARED FOR **NASA MANNED SPACECRAFT CENTER** UNDER CONTRACT NAS 9-4079

TRW *SYSTEMS*

FINAL REPORT · AUGUST 1965

Volume III. PROGRAM PLANS

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DEFINITION OF TELEMETRY EQUIPMENT FOR APOLLO PASSIVE LUNAR SCIENTIFIC EXPERIMENTS (TAPLE)

Final Report

Volume III. Program Plans

5371-6006-RU-000

Prepared for
NASA MANNED SPACECRAFT CENTER
Under Contract NAS 9-4079

August 1965

Approved R C Booton Jr.
R. C. Booton, Jr.
Director
Communication Laboratory

~~AVAILABLE TO NASA HEADQUARTERS ONLY~~

TRW SYSTEMS GROUP
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1.0 DEVELOPMENT PLAN AND SCHEDULES

1.1 REQUIREMENTS AND FIRST DESIGN REVIEW

The program follows the 18 month schedule shown in Figure 1. The design and development of the basic circuits start immediately upon notification of go-ahead. During the first two months, a review of all requirements is conducted. Particular emphasis is placed on the review of the telemetry and command requirements for the scientific experiments. At the end of this period, a design review is held to present and justify design changes. At this time the system concept, including justified changes, is established.

1.2 PRELIMINARY DESIGN AND BREADBOARD MODEL

During the first five months, circuits are designed and complete circuit descriptions and circuit design specifications generated. This includes physical configuration drawings, informal circuit schematics, and informal module assembly drawings. A breadboard model of the electronic subassemblies of the system is completed. During this period, the thermal control subsystem undergoes

- Sun shield material tests
- Second surface mirror UV tests
- Assembly heat leak tests
- Louver efficiency tests

The design, development, and updating of the breadboard models continue through the eighth month.

1.3 SECOND DESIGN REVIEW

At the end of five months, a second design review is held. At this design review the implementation of design concepts is reviewed and the adequacy verified. Also, at this review, any advance procurement requirements are established.

1.4 ENGINEERING MODELS

During the next three months, the first engineering model is fabricated, which includes all of the latest circuit design information available as a result of the breadboard model tests. Test procedures are also generated during this period.

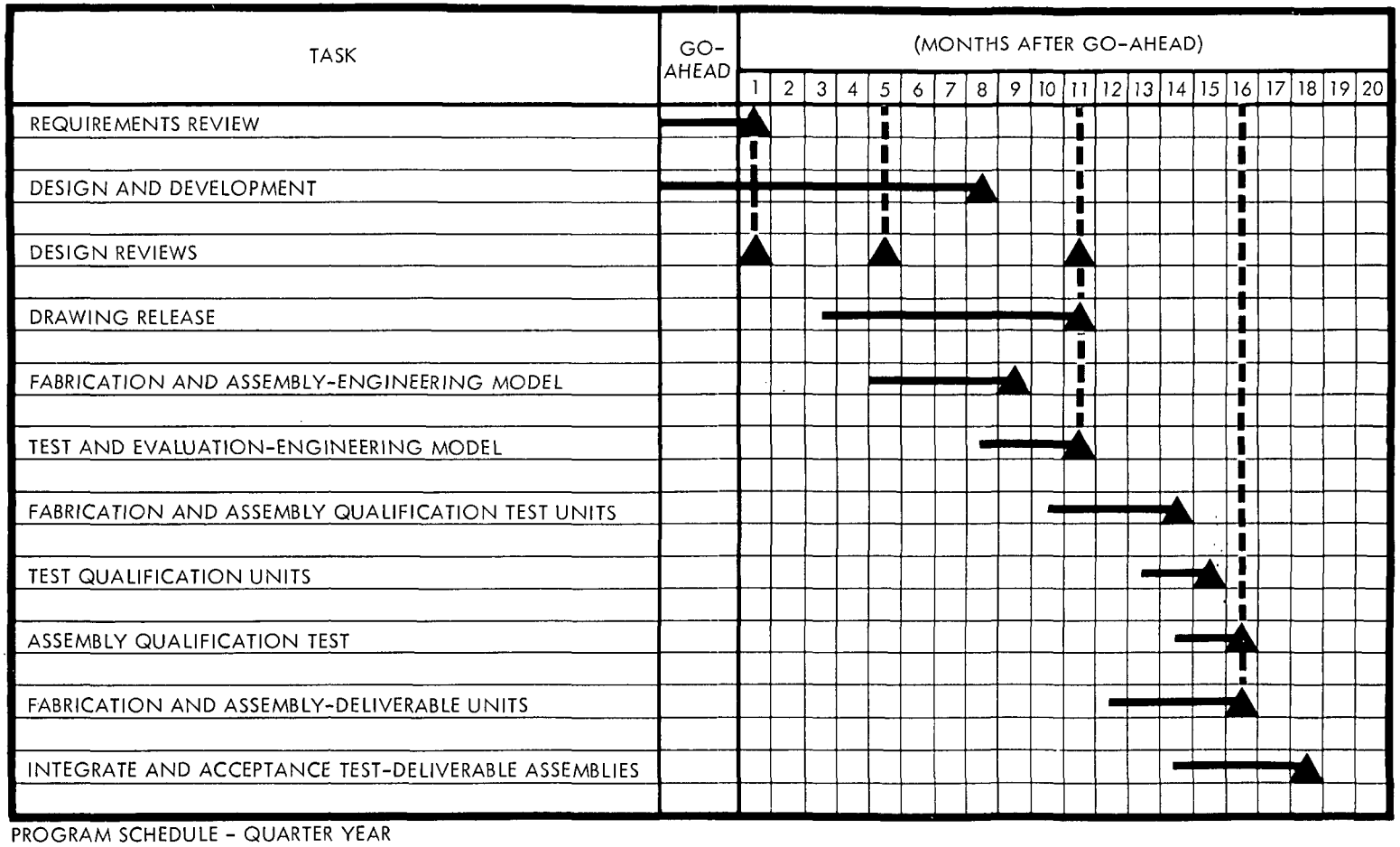
TASK
GO-AHEAD
(MONTHS AFTER GO-AHEAD)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
REQUIREMENTS REVIEW
DESIGN AND DEVELOPMENT
DESIGN REVIEWS
DRAWING RELEASE
FABRICATION AND ASSEMBLY-ENGINEERING MODEL
TEST AND EVALUATION-ENGINEERING MODEL
FABRICATION AND ASSEMBLY QUALIFICATION TEST UNITS
TEST QUALIFICATION UNITS
ASSEMBLY QUALIFICATION TEST
FABRICATION AND ASSEMBLY-DELIVERABLE UNITS
INTEGRATE AND ACCEPTANCE TEST-DELIVERABLE ASSEMBLIES
PROGRAM SCHEDULE - QUARTER YEAR

Figure 1. Program Schedule

Test and evaluation of this first of two engineering models parallel the fabrication of the second engineering model.

Tests on this model consist of both subassembly tests and tests on the complete TAPLE assembly. For example, the thermal control subassembly tests establish and verify the adequacy of the thermal control design. The subassembly tested consists of the housing complete with insulation and actual or simulated antenna and cables, louvers, sun shield, and simulated heat producing electronic components. The antenna tests conducted on an antenna test range are performed in series with the thermal tests. The second engineering model is delivered to the customer.

1.5 THIRD DESIGN REVIEW

A third design review is held at the end of the 11th month, which coincides with the completion of the engineering model tests. The purpose of this third design review is to ensure that the design, as detailed, meets the performance requirements. This review is held prior to the release of drawings for fabrication. The material to be reviewed includes, but is not limited to

- All drawings prepared for release, and supporting specifications
- Supporting test data
- Failure history and all other reliability data

1.6 PROTOTYPE ASSEMBLIES

Two prototype assemblies are fabricated for qualification test purposes. The subassemblies of the first prototype are qualified on a unit basis. The second prototype is qualified as an assembly. Fabrication, assembly, and qualification testing of these two prototypes are performed during the five month period between the 11th and the 16th month.

1.7 PRODUCTION UNITS

Three flight assemblies and three spare assemblies are fabricated. In order to conserve time, the fabrication and assembly of parts of these production units are paralleled with fabrication and testing of the prototype models. Integration and acceptance tests prior to delivery of these production units are performed during the four month period from the 14th through the 18th month.

2.0 COMMAND AND DATA HANDLING PLAN

2.1 SCOPE

The command and data handling plan describes the signal characteristics, signal processing, and equipment used in the operation of the TAPLE assembly when placed on the lunar surface. The two major aspects are the up-link which provides discrete commands and data commands to TAPLE and the down-link which transmits the lunar real time or stored telemetry data.

2.2 UP-LINK

The recommended up-link frequency is 2101.8 mc which is also the Apollo LEM command frequency. Modulation and coding is such that no interference will be possible. The system is not coherent and therefore there is no relation between up and down link frequencies. The up-link transmits the discrete commands, approximately 38 bits in length, and the data commands, 525 bits in length, in an uninterrupted bit stream to the TAPLE assembly.

2.2.1 COMMAND FORMATS

TAPLE Specification EQ4-176, the command decoder, is referenced here as a source of additional detail information.

2.2.1.1 Discrete Commands

The discrete commands are NRZ format and the bit rate is 1000 bits per second (bps). There are no sub-bits as in Apollo. The bit assignments are as follows:

Preamble	6 bits	minimum (all "0")
Word Sync	1 bit	("1")
Address	6 bits	Identifies TAPLE assembly to be commanded and the fact that a discrete command is being transmitted
Command complement	6 bits	
Command	6 bits	
Timing	13 bits	(all "1")
	38 bits	uninterrupted

2.2.1.2 Data Commands

The PCM encoder has among its operating modes a flexible format mode in which the data multiplexing is controlled by a memory. This memory can be changed from earth by means of the data commands. The format is NRZ, the bit rate is 1000 bps, and the bit assignments are as follows:

Preamble	6 bits	minimum (all "0")
Word Sync	1 bit	("1")
Address	6 bits	Identifies TAPLE assembly to be commanded and the fact that a data command is being transmitted.
Data	512 bits	
	525 bits	uninterrupted

2.2.2 COMMAND SIGNAL CHARACTERISTICS

The NRZ command signal bi-phase modulates a 2 kc sine wave subcarrier and is then summed with a 1 kc sine wave reference. The three wave forms are properly phased and coherent for ease of demodulation. This composite signal directly modulates the command carrier. The deviation of the RF carrier is maximized (relative to the RF carrier, this is specified as 3.0 radians peak requiring 1.0 volts peak in the MSFN ground equipment S-band RF receiver exciter subsystem (JPL DOR-1086-DSN).

The major difference between TAPLE and Apollo, relative to commands, is that the 70 kc subcarrier is by-passed for TAPLE.

2.2.3 COMMAND PROCESSING

The primary command responsibility is exercised by Mission Control Center (MCC), Houston. The primary command link is via the control center to the selected station with lunar visibility. All commands are transmitted to TAPLE in accordance with a detailed operations plan. Prior to actual commitment of a command to TAPLE, acknowledgement is secured from a TAPLE operations director.

The Apollo 642 B Univac computer at the transmission site is loaded with the scheduled commands from the MCC to be called up at the scheduled time. Alternately, real time commands are sent from MCC using the computer as a real time distribution center. These are proposed Apollo modes.[1]

Upon command call-up, command information is processed from the computer by the up-data buffer (CPN 766-0601-000). The data subcarrier oscillators (CPN 126-0447-010) are bypassed for direct modulation of the exciter (DOR-1086-DSN). The power level is amplified to approximately 10 kw in the 10 kw power amplifier (GSFC-TDS-XTR-2) and fed to the 30 foot antenna system. If the 85 foot antenna system is used, the command power can be reduced to 2 kw.

2.2.4 VERIFICATION

To verify the reception of a command by the TAPLE package, real-time quick-look data processing is required. Bi-level signals from the decoder verify command processing completion of a specific command. Also key changes in the operating mode or data aid in verifying command reception. Repetition of a command, say three times in succession, increases probability of command reception.

2.3 DOWN-LINK

The recommended down-link frequencies are 2278.3 mc, 2276.7 mc, and 2277.5 mc, to be used in that order for the first three TAPLE assemblies. There are no coherent frequencies relative to the up-link frequency which is common for all assemblies. The down-link transmits the real-time or stored PCM telemetry data.

2.3.1 DATA MODES AND FORMATS

The PCM encoder specification, EQ4-171, is referenced here to facilitate obtaining additional detail information.

---

[1] Peltzer, K. "Fundamentals of Apollo Unified S-Band System," GSFC No. X512-65-213.

2.3.1.1 Real Time Mode

The PCM encoder operates at six bit rates:

10,240 bps
5,120 bps
2,560 bps
1,280 bps
640 bps
160 bps

Four types of formats are provided:

Format A - Fixed
Format B - Flexible
Format C - Accel subcom
Format D - Single data

The main frame consists of 64 words. Word length is 8 bits. Frame synchronization is a unique code in main frame words 1 and 2, and words 33 and 34. Mode identification is contained in main frame word 3. Subcom position identification is contained in main frame word 4. One 64 word subcom is contained in main frame word 62. Two 32 word subcoms are contained in main frame words 63 and 64. Time correlation data is contained in words 31 and 32 of the subcom in main frame word 64.

2.3.1.2 Data Storage Mode and Readout

Data can be stored in one of two modes by command. In the fast scan store mode, data is stored at the highest bit rate in a continuous stream. In the duty cycle store mode, data is stored at any bit rate, one frame at a time. At a 17.1 minute recurring period, memory readout occurs at a command selected operating bit rate.

2.3.2 DATA SIGNAL CHARACTERISTICS

The PCM encoded data bi-phase modulates a 10,240 cps square wave subcarrier oscillator in the NRZ-Ml format. The RF carrier is phase-modulated with a peak deviation of 1.25 radians.

2.3.3 DATA PROCESSING

The signal is received at the MSFN station by the antenna system and transferred to the S-band receiver (JPL-DOR-1086-DSN). The receiver is operated with the narrowest phase-lock loop bandwidth setting, 50 cps. Channel B is used for TAPLE with an IF bandwidth setting of 600 kc (-3 db points). The output is the video detected output with the 210 kc (-1 db) bandwidth setting.

The receiver output is tape recorded along with station acquisition time for later detailed processing. For operations where commands are not scheduled, this is the limit of the data acquisition operation.

2.3.3.1 Command and Quick-Look Processing

For command operations or quick-look operations, the tape recorded signals are processed further to provide real time quick-look data.

The receiver output (simultaneously to being recorded) is processed through the TAPLE special SCO demodulator (EQ4-169). The output is compatible with the remaining MSFN station equipment, the PCM data decommutation system (GSFC-553-64-10), and the Univac CP642-B computer with output line printer.

The PCM data decommutator is patch programmed to handle the various TAPLE formats which may be used during command or quick-look operations.

The computer requires a program to provide a quick-look printout to confirm command reception and to allow monitoring the state of health of the TAPLE assembly through housekeeping measurements.

2.3.3.2 Experiment Data Processing

The recorded receiver output data from the various ground stations is accumulated at a central location and arranged in chronological order. In the computer, time is correlated and all data is referenced to universal time. Computer programs are prepared to separate the experiment data for printout and formulation of buffer tapes. These are given to experimenters for analysis and further processing.

3.0 MANAGEMENT PLAN

3.1 THE MANAGEMENT ORGANIZATION

Responsibility and authority for the follow-on TAPLE program is vested in one individual, the program manager. He is responsible for the general management of all activities required to meet the technical, schedule, and financial obligations of this program. The program manager is supported, as necessary, by a program organization consisting in part of resources assigned exclusively to the program office and in part of resources assigned for program work by those functional organizations which have responsibility for carrying out subelements of the TAPLE program.

The program office, through the program manager and assistant managers, directs and evaluates the total program, and assesses the performance of the functional organizations and other contributors in meeting established goals. This program office/functional organization relationship results in clear lines of communication and insures that control actions will be handled promptly by program office or functional managers depending on the type of action required.

The functional organizations are divided into first tier subelements, or work packages with a work package manager responsible for each work package. Each work package may be further divided as necessary into basic work units with a work unit manager responsible for each work unit. Each work unit consists of that work required to meet a clearly defined set of objectives as described in a task description and which are planned and accomplished in accordance with an approved schedule and budget. Therefore, each work package and work unit manager is responsible for the design, development, fabrication, and test tasks in his package as well as schedule and cost control.

3.2 WORK BREAKDOWN STRUCTURE

The work breakdown structure describes the manner in which the TAPLE program is divided into manageable work packages and work units. These subelements are so structured as to define tasks with reasonably short time spans, capable of being performed by discrete parts of the program organization. This management oriented work breakdown structure identifies each work package and work unit manager, each of

which has a definable statement of work, schedule, and budget. The work breakdown structure is designed to achieve ease of management and internal operation of the total program organization. Work elements at the various levels closely match the missions of the functional groups to which they are assigned. Interface problems between laboratories or departments are thereby minimized. The work breakdown structure is a most important plan which is necessary for the management of the TAPLE program. Budgets and cost control procedures are designed to be compatible with this structure. Schedules, PERT, and all reporting documentation also follow this plan. A recommended TAPLE work breakdown structure is presented in Figure 2.

3.2.1 WORK AUTHORIZATION

Authority to expend effort and resources in performing TAPLE program tasks is conveyed to each work package and work unit manager by means of a work authorization. Work authorizations are initiated and authorized by the program office and are identified by a sequence number consistent with the work breakdown structure. All TAPLE program revisions are officially executed by issuance of work authorizations. Changes in the specifications are also implemented by work authorizations in order that effects on costs and time may be tied to each change in technical requirements. This procedure assures that program management is kept aware of all changes and their impact on program schedules and costs.

3.2.2 FINANCIAL CONTROL

The TAPLE program manager is the focal point of responsibility for ensuring program technical excellence, schedule compliance, and financial management. The assistant manager of program control is delegated the responsibility of implementing effective financial management through budgeting and cost control.

The work breakdown structure is the framework for a preparation of budgets and establishment of cost control techniques. Detailed cost estimates for each task in the work breakdown structure are prepared by the responsible functional managers. After the estimates have been reviewed and approved by the program office they become the basis

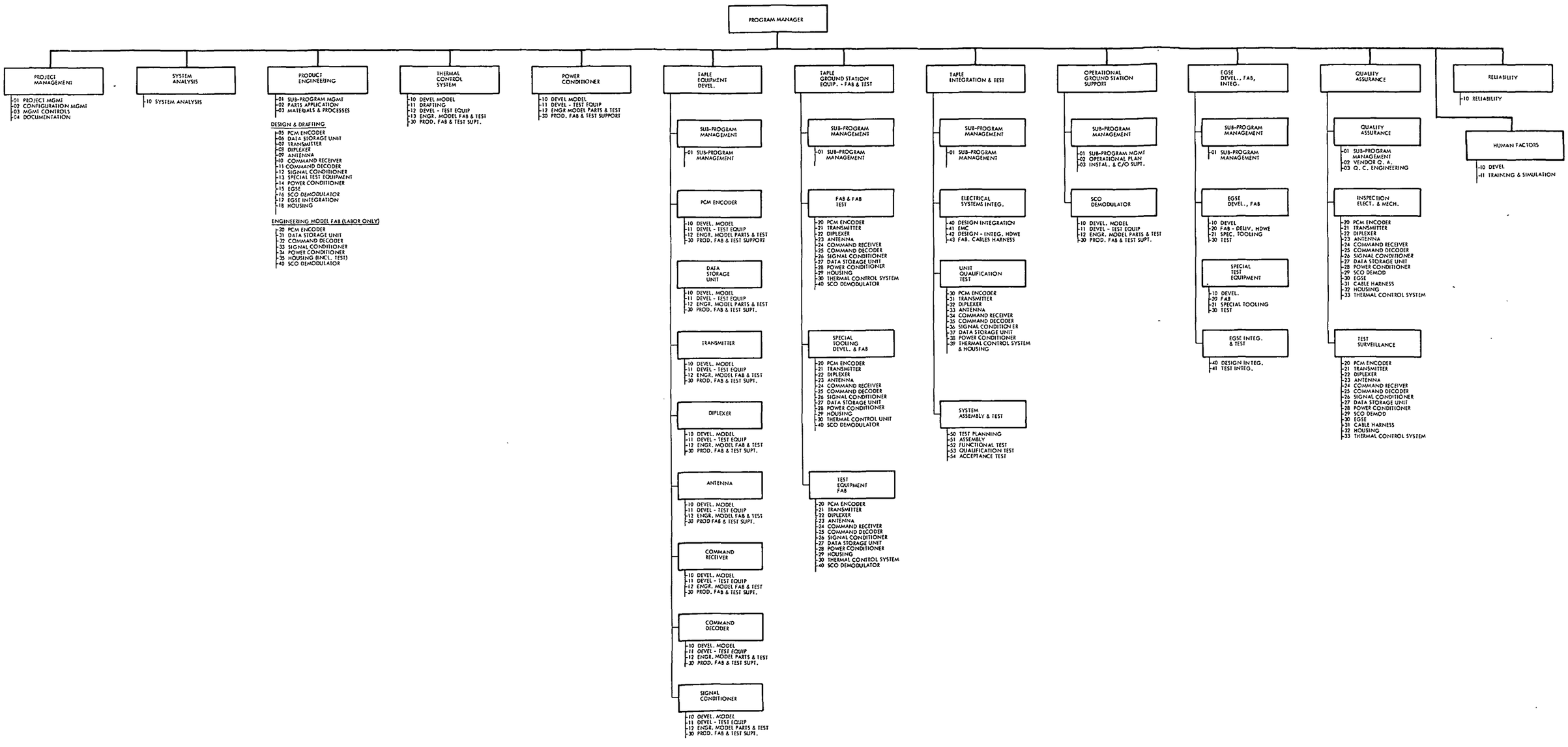

Figure 2. TAPLE Work Breakdown Structure

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for preparing program budgets against which costs are collected and accumulated for analysis. All budgets are approved by the work unit manager, work package manager, the appropriate department manager, the TAPLE program manager, and are included as part of the work authorization package. This budget as established will be the total dollar amount authorized for the TAPLE program including procurement and in-house effort. All budget revisions are prepared and approved in the same manner.

A cost collection and reporting system for the TAPLE program identifies costs by contracted tasks and the discrete units of work. Costs are also identified by element of cost (labor, material, travel, computing services, subcontracts, etc.) and organization code. Pertinent computerized cost data is provided to the functional and program office managers on a weekly basis within four days after the end of each week. Cost status reports are prepared to show actual costs, budgets, and deviations from budgets for each work unit, work package, and program summary. These elements are shown for the current period, total to date, and total at completion. The following reports provide the program manager with an up-to-date financial position on the TAPLE program.

3.2.2.1 Program Status Report

This report presents for each program task the costs expended during the current reporting period for each labor and other direct cost category, the cumulative expenditures to date, the estimate to complete, the estimated costs to be expended at completion of the task, the task budget, and the dollar variance over or under the budget amount.

3.2.2.2 Program Control Chart - Direct Cost Status

This chart presents graphically the plan versus the actual direct dollar cost for the program by task. This allows management a visual presentation of cost data.

3.2.2.3 Program Control Chart - Funding Status

This chart presents graphically a comparison of authorized funding, expenditure plan, and actual dollar expenditures.

3.2.2.4 Program Control Report - Equivalent Direct Manpower

This report presents the allocation of direct manpower to the program. A comparison is made in terms of man-months of effort or hours between the original manpower expenditure plan, the current manpower expenditure plan, and actual manpower expenditures.

3.2.2.5 Program Control Chart - Equivalent Direct Manpower

This chart presents a graph of the manpower expenditure plan and actual manpower expenditure from the inception of the program through the current reporting period.

The key to successful management is continued evaluation of progress and operating plans and taking corrective action where necessary. The program manager, therefore, holds regularly scheduled meetings with all work unit and work package managers to discuss and formulate decisions on cost problems.

3.3 SCHEDULE CONTROL

The contractor controls schedules through the use of NASA PERT/TIME using a NASA-C program. Implementation is accomplished using an IBM 7094 computer or equivalent. This technique is supported by a cost estimating and budget reporting system that relates financial data to program accomplishment.

A master PERT network and supporting "fragnets" are prepared by responsible work unit managers under the direction of the program office. A "top-down" approach is used and each work unit and work package is coded to relate to the codes used in the master network and work breakdown structure. The contractor processes the TAPLE updating information biweekly, and furnishes NASA MSC the processed networks and related reports. The following procedure is recommended:

a) The contractor processes the biweekly updating of the networks and provides identical inputs to NASA.

b) NASA notifies the contractor by TWX of requests for clarification or amplification, if required, together with any comments or suggestions.

c) The contractor program office prepares network status reports for evaluation by NASA and the program office.

Each activity within the networks is defined in detail and time estimates obtained from the activity responsible work unit manager. These inputs are used for updating the program master file. Each update may include

- Change of time estimates
- Change of activity or event descriptions
- Addition or subtraction of events and/or activities
- Revision of network logic or constraints

3.4 TAPLE PROGRAM CONFIGURATION MANAGEMENT

3.4.1 DEFINITION OF CONFIGURATION MANAGEMENT

Configuration management is the systematic identification, control, and accounting for the end products of the TAPLE program. The end products are the deliverables of the program effort to fulfill contractual obligations. End products may include hardware, documentation (specifications, drawings, etc.), facilities, material, support, and/or any combination of these.

The function of identification includes the definition and identification of approved configuration continuously from the time of establishing a baseline through the intended life of a configured item.

The function of control includes the control of the effect of changes and the planning for their economical and expeditious implementation. The function of accounting includes the continuous recording of the status of products to constantly reflect the approved configuration.

3.4.2 GENERAL REQUIREMENTS OF CONFIGURATION MANAGEMENT

Requirements of configuration identification, control, and accounting should be in consonance with the following basic objectives of configuration change management.

a) The configuration of products is completely and accurately defined at all times subsequent to initial design release by means of formally released contractor engineering configuration data.

b) Products are fabricated and tested in accordance with applicable, approved, and formally released engineering configuration data.

c) Configuration changes to products are processed by formal engineering paper for systematic coordination and evaluation by authorized organizations to determine their approval and implementation, with the following limiting policies and objectives:

- Only changes to fulfill technical requirements or which will improve contractor performance or provide advantages to the customer are implemented.
- All engineering and configuration data affected by accepted and approved changes are revised as necessary to reflect the change.
- Approved changes result in appropriate changes to all related support elements - manuals, handbooks, support equipment, etc.
- All actions related to the submission, analysis, approval, and implementation of changes are adequately documented.
- Accepted changes to engineering configuration data are properly implemented to assure that the cost of the change is minimized and that the product is produced as specified.
- The incorporation of retrofit engineering changes is made only when they are mandatory for functional reasons or when retrofitting is to the customer's advantage.

d) Configuration change management provisions are established and maintained on all subcontracted systems or major components designed by a supplier.

e) Formalized configuration identification, status, and verification reports are periodically made available for customer surveillance.

3.4.3 CONFIGURATION MANAGEMENT AND MILITARY STANDARDS

Configuration management is based on and incorporates pertinent portions of the latest applicable military standards and specifications and

generally accepted industry practices, supplemented and modified where needed by contractor procedures. In particular, configuration management conforms to the applicable provisions of NPC 500-1.

3.4.4 MAJOR CONFIGURATION MANAGEMENT FUNCTIONS

Configuration management is divided into three major functions:

- Change evaluation and control (CEC)
- Change administration and planning (CAP)
- Configuration identification and accounting (CIA)

3.4.4.1 Change Evaluation and Control (CEC)

The CEC function is to review and approve proposed changes. These are executed by the configuration control board (CCB) chaired by the project manager or his designee.

The principal objectives of the CEC function are to:

a) Identify and correlate engineering changes to affected end products.

b) Assure coordination and evaluation of proposed engineering.

c) Assure the approval and adoption of engineering changes that are:

Mandatory to "make work" or meet specification requirements

Technically suitable

Appropriate to optimize cost and meet schedule objectives

d) Ensure that approved engineering changes comply with contractual requirements.

e) Establish a plan for incorporating approved engineering changes expeditiously.

3.4.4.2 Change Administration and Planning (CAP)

The CAP function is the process by which the housekeeping function of the CCB and the implementation planning for all changes is accomplished as an integral part of the configuration management structure.

The principal objectives of the CAP function are:

a) Processing engineering changes from the point of origin, through the approval/disapproval cycle, to the release of engineering data depicting the requirements of the approved engineering changes.

b) Assuring that all approved engineering changes are planned for and incorporated.

3.4.4.3 Configuration Identification and Accounting (CIA)

The CIA function is the process by which the approved configuration and changes are: (1) completely, accurately, and continuously identified, (2) administratively controlled, and (3) reported.

The principal objectives of the CIA function are to:

a) Continuously document the precise technical and configuration description of the end products.

b) Provide a central control point for the identification documentation of changes.

c) Continuously account for configuration status.

d) Coordinate and report, as required, certifications that the actual end products are in fact as established by the appropriate documentation.

3.4.5 ENGINEERING DATA MANAGEMENT (EDM)

The EDM function centralizes the services and establishes the necessary controls associated with the handling and processing of engineering data.

The principal objectives of the EDM function are:

a) Assuring effective, efficient, and economical management of all engineering data (except reports).

b) Maintaining configuration identification and accounting procedures.

c) Preparing required engineering associated lists.

3.4.6 CONFIGURED ITEM

A configured item is defined as any element of hardware or software system which requires the application of configuration management techniques and which is selected by the contractor or the customer in accordance with the following criteria:

a) The item is procurable as a separately identified entity to be manufactured, tested, accepted, delivered, maintained, and logistically supported on an item basis.

b) The physical and functional characteristics of a configured item is such that its configuration can be controlled and documented economically regardless of the number of changes approved for incorporation.

3.4.7 BASELINES

At a predetermined point in time the TAPLE design is fully defined and documented as the starting point for configuration management. This means that from that point in time all subsequent changes made against that design or configuration are identified, analyzed, accounted for, and documented. This design or configuration, thus established, is defined as a baseline for all future control.

During the life of the TAPLE program, it may be necessary to establish more than one "baseline." The concept of baseline configuration is applied to individual items which are selected as configured items. As a result, the baselines for various items may be established at different times in the program schedule depending upon the state of design and/or development of the individual configured item.

It is essential that the baseline for each configured item be clearly delineated by appropriate engineering drawings, along with their associated data, and specific configuration documentation. The latter includes baseline configuration reports for each configured item and baseline configuration indexes which summarize configured item baselines by subsystem groupings.

4.0 RELIABILITY PLAN

4.1 GENERAL

This document sets forth the minimum reliability requirements for the TAPLE program. These requirements include the establishment and control of the reliability engineering program from initiation of design through the delivery of hardware.

4.1.1 APPLICABILITY

This document is applicable to the extent invoked in the contract, work statement, or purchase order. If conflict of requirements exist between this document and the contract or work statement, the latter has precedence.

4.1.2 RELATIONSHIP TO OTHER CONTRACT REQUIREMENTS

Nothing in this document should be construed as a requirement for duplication of effort. Where organizational responsibility overlaps from one group to another the overlap is clearly delineated in the reliability program plan and other pertinent documents.

4.1.3 ACTIONS AND PREROGATIVES OF THE GOVERNMENT

All data and documentation generated for the contract effort by the contractor including all design and test data and all quality program documentation are subject to continuous examination, evaluation, and inspection by NASA MSC or its designated representatives.

4.1.4 APPROACH

The reliability program provisions require

a) Full management planning and control of the reliability effort,

b) Definition of the major reliability engineering tasks and their relations to design and development,

c) Assurance of reliability through proper production, test, and evaluation, and

d) Continuous status reporting and control of the reliability program through proper documentation and reporting.

4.1.5 APPROVAL AND REVIEW BY NASA MSC

The provisions contained in this document plan that certain documentation is submitted by the contractor to NASA MSC for approval or review. These terms as used herein are interpreted as follows.

4.1.5.1 Approval

Items of documentation requiring NASA MSC approval are approved in writing by NASA MSC within the time specified in the contract. The contractor does not implement documents in this category until approval is granted. Neither approval nor waiver of approval relieves the contractor of his obligation to meet the requirements of the contract.

4.1.5.2 Review

Documents submitted for NASA MSC review are received by NASA MSC not less than 2 weeks prior to intended use by the contractor. These documents are implemented by the contractor if he has not been notified of disapproval within the 2 week period.

4.2 PROGRAM MANAGEMENT

The contractor provides one clearly identified group within his organization which is responsible for the management of the reliability program. The individual designated as head of this group has authority to discharge his responsibility, has direct unimpeded access to top management, and devotes full time to this effort. Many of the reliability tasks may be performed in other groups of the contractor organization. It is, however, the responsibility of the reliability management group to monitor these tasks and to ensure that all of the tasks are accomplished effectively.

4.2.1 RELIABILITY PROGRAM PLAN

The contractor prepares a detailed reliability program plan covering the reliability activity on the TAPLE program. The program plan details the overall approach, and step-wise procedures by which the contractor intends to ensure compliance with this document and the requirements of the contract. Cost and scheduling data are included as an integral part of the plan. The contractor invokes the requirements of this document on each subcontractor where applicable.

4.2.1.1 Program Plan Submittal

The contractor submits to NASA MSC, for review and approval, the reliability program plan as a separate section of the overall TAPLE program plan. This plan, as a minimum, covers all major elements of the program in sufficient detail to serve as an adequate basis for specifics of the reliability program.

4.2.2 RELIABILITY PROGRAM REVIEWS

The contractor and NASA MSC jointly hold formal reliability program reviews to assess progress and effectiveness and determine the need for adjustments. These reviews are scheduled at major milestones in the program plan and periodically as prescribed by NASA or as requested by the contractor. Each review is documented by the contractor and resultant revisions submitted to NASA MSC for approval within 30 days following the review. Reliability program changes within the scope of work of the contract are implemented as agreed upon at the review meetings.

4.2.3 RELIABILITY PROGRAM CONTROL

The contractor defines, in the reliability program plan, his system for close management control and audit of the reliability engineering program. Insofar as practical, this system utilizes the NASA reporting system prescribed for the overall contract effort with supplemental provisions as agreed on with NASA MSC. This system accomplishes the following for reliability program management:

a) Identifies each reliability task with organizational element responsible for its execution, detailed time-phasing data, and complete reliability milestone identification.

b) Provides, for each reliability task, a detailed listing of man-hours, materials, facilities, services, and support with associated costs by time-phase.

Progress in implementation of the reliability program control is reported periodically.

4.2.4 RELIABILITY INDOCTRINATION AND TRAINING

The contractor conducts an effective reliability training program for all employees whose work influences the reliability of the products being developed. This training is a continuing program and the detailed outline of this training program is included in the reliability program plan.

4.2.5 SUBCONTRACTOR AND SUPPLIER CONTROL

4.2.5.1 General

The contractor is responsible for ensuring that equipment obtained from subcontractors and suppliers meets the reliability requirements of the overall TAPLE assembly. All subcontractors include provisions for review and evaluation by NASA MSC of the subcontractor's reliability effort.

4.2.5.2 Reliability Program Requirements for Major Subcontractors

Appropriate provisions of this document are invoked by the contractor on all major subcontracts and on suppliers of all major components used in the TAPLE assembly. The initial program plan includes the extent to which these provisions are covered in the contract for each subcontractor and supplier. These provisions are subject to review by NASA MSC. Additional subcontractors and suppliers selected subsequent to the initial program plan submittal are reported in the periodic progress reports for NASA MSC review.

4.2.5.3 Resident Representatives

Where major subcontracts involving critical subsystem or components are required, the contractor places resident technical representatives in the subcontractor's facility to monitor and assist in the reliability program. These representatives should have the competence to judge and the authority to disapprove the subcontractor's design specifications and procedures where reliability is considered to be in jeopardy, and to reject hardware produced which is below prescribed quality standards. Subcontracts requiring this means of control are identified in the reliability program plan.

4.2.5.4 Minimum Reliability Controls for Components Not Classified as Major

Components within the TAPLE assembly which are not

classified as major and do not require the supplier to maintain a formal reliability program are, as a minimum, controlled by specifications. The reliability program plan includes a listing of the items requiring control and the control provisions to be used.

4.3 RELIABILITY ENGINEERING

This section describes the basic elements of the reliability engineering program. The contractor includes in his reliability program plan all of the requirements of this section unless specifically deleted by the work statement, contract, or purchase order.

4.3.1 DESIGN SPECIFICATIONS

The contractor's reliability organization reviews and concurs with all contractor generated design specifications after determining that these specifications cover all items of hardware at the system, subsystem, and component level. Each specification reflects and states the mission profile performance requirements, environmental profile requirements, pertinent test criteria (including over-stress) safety margins, derating factors, and apportioned reliability goals (including definition of satisfactory performance) for the TAPLE element in question.

4.3.2 RELIABILITY PREDICTION AND ESTIMATION

Reliability prediction models are initiated as part of the design trade-off studies to permit design decisions early in the conceptual stage. These models are revised as required during the program to reflect changes in the system design and to reflect inputs from reliability analyses and test results. The prediction models used are: (a) to determine the reliability goals for each item of the TAPLE assembly, (b) as a basis for redundancy studies, (c) as a guide for additional failure mode, effects, and criticality analysis, (d) to reallocate the apportioned reliability goals, (e) to specify the numerical reliability goals to be attained during testing, (f) as a basis for test programming, and (g) to emphasize potential problem areas.

4.3.3 FAILURE MODE, EFFECT, AND CRITICALITY ANALYSIS

In conjunction with the reliability predictions, the contractor prepares failure mode effect and criticality analyses to determine all possible modes of failure and their effects on mission success. The primary objective of these analyses is to discover all critical failure

areas and remove susceptibility of such failures to the system. The analysis starts at the system level and expands downward to the component level. Each potential failure is analyzed with the probability of occurrence and probable effect on mission success of the space system. These failure mode analyses are used as a major consideration in each design review and they provide an important criterion for test planning and establishment of checkout procedures, use time (or cycles), logging requirements, and the required frequency of monitoring during checkout and through the launch operation sequence.

4.3.3.1 Failure Cause Analyses

Each failure listed in the failure mode, effect, and criticality analyses is analyzed for the probable causes of failure and to recommend preventive actions where appropriate. The failure cause analyses also identify the potential weakness in the design and the means to eliminating it.

4.3.4 PROBABILITY APPORTIONMENT

The TAPLE reliability requirements of 3.1.2.1, Specification SY1-11, System Specification Telemetry Equipment for Apollo Passive Lunar Scientific Experiments, are allocated into subsystem and component goals. In making the apportionments, the degrading effects of time and environments are factored into the analysis. The apportionments are updated at the conclusion of major milestones in the TAPLE program. These milestones are defined in the reliability program plan.

4.3.5 RELIABILITY STUDIES

The contractor conducts worst case studies, parametric analyses, and environmental studies. These studies are performed to search out critical weaknesses, the effects of subsystem and component variation, and to determine the local environments the items are subject to (as opposed to the environments listed in the general specification).

4.3.6 MAINTAINABILITY AND ELIMINATION OF HUMAN INDUCED FAILURE

The contractor implements a human engineering program to assure adequate consideration of maintainability and to eliminate human

induced failure in the TAPLE assembly. The human engineering program ensures that the system is capable of being handled, maintained, and operated without hazard or undue degradation of performance when performing intended functions in the environments specified in Table I of Specification SY1-11.

This program begins in the design conceptual stage and continues through the design and manufacturing phases. If this program is to be performed by a group other than reliability, the contractor identifies in the reliability program plan the group performing the task, and cross references the human engineering plan to the reliability program plan.

4.3.7 DESIGN REVIEW PROGRAM

The contractor establishes and conducts a formal program of planned, scheduled, and documented design reviews at the system, subsystem, and major component levels. These reviews are comprehensive critical audits of all pertinent aspects of the design, particularly its reliability, and are conducted at all major milestones in the program.

The contractor notifies NASA MSC 15 days prior to each design review. Included on the notification are:

a) A detailed description of the system element to be reviewed, with the firm date, time, and location of the review.

b) A detailed agenda, schedule, and check list of design aspects to be reviewed.

Participation in the design reviews includes personnel from design, test, fabrication, reliability, quality, parts application, and other areas of the contractor's organization as well as NASA MSC representatives (at the discretion of NASA MSC). All participating members of the contractor's design review sign all design review reports to signify concurrence. The reliability group is responsible for follow-up on action items to ensure completion.

4.3.7.1 Subcontractor Design Reviews

The contractor invokes these requirements on all major subcontractors. Appropriate representatives of the contractor

participate at his discretion in the subcontractor's formal design reviews as well as NASA MSC personnel on an observer basis.

4.3.7.2 Engineering Design Changes

All proposed engineering changes to be made after the final design review are submitted to the review board or design change board for analysis and approval. When the change is considered warranted, a formal design review is conducted prior to release of the change.

4.3.8 FAILURE REPORTING AND CORRECTION

The contractor employs a closed loop failure reporting, analysis, correction, and data feedback system. This system reports all failures occurring during fabrication, handling, test, checkout, and operation of the TAPLE assembly.

The contractor submits a detailed description of the failure reporting and correction system, including procedures, organizational responsibilities, format, and numbering of reports for NASA MSC approval as a part of the reliability program plan. If the failure reporting and corrective action system is submitted as a part of the quality program plan, the paragraph number is referenced in the reliability program plan. He also submits periodic listings each reporting period of failure reports, failure analysis reports, and corrective action reports. Individual failure reports, failure analysis, or failure correction reports should be referenced by number but need not be submitted unless specifically requested by NASA MSC.

4.3.8.1 Subcontractor Failure Reporting and Correction

The contractor establishes these requirements for each subcontractor. The reliability program plan includes the names of the subcontractors and the description of the subcontractors' failure reporting and correction systems. Additional subcontractors and suppliers selected subsequent to the initial program plan submitted are reported in the periodic progress reports for NASA MSC review.

4.3.9 STANDARDIZATION OF DESIGN PRACTICES

The contractor's reliability organization in conjunction with the quality organization is responsible for reviewing the design practice

and processing procedures. These reviews are made to determine their adequacy in meeting reliability and quality requirements of the contract. Monitoring is also made to ensure continuing compliance. Where NASA design criteria are available they are incorporated into the contractor's and subcontractors' design standards system to the extent presented in the contract. The contractor uses his own existing standards and specifications, but modifies them to meet the quality and reliability requirements of the contract. All standards are subject to review by NASA. Deviation from standard practices is given particular evaluation and review. Typical standardization areas are: (a) process specifications, (b) fabrication, assembly, and marketing standards, (c) drafting practice and drawing specifications, (d) general design specifications for electronic, mechanical, hydraulic, and pneumatic assemblies, (e) general guides for design simplification, and (f) procedures for ensuring formalization in drawings and specifications of "quick fixes" made to correct failure in test or field use.

4.3.9.1 Subcontractor Design Practices

The contractor reviews the standards of all subcontractors to ensure compatibility with the contractor's system. The subcontractors' standards are subject to inspection by NASA MSC.

4.3.10 PARTS AND MATERIALS PROGRAM

The contractor submits a description of his parts and materials program in the reliability program plan. This program covers the selection, specification, qualification, and application review of parts and materials for all items to be used in the assembly. The contractor defines in the reliability program plan the organization and procedures to be employed in the parts and materials program. Progress and problem areas encountered are reported in the periodic reliability progress reports.

4.3.10.1 Approved Parts and Materials List

The contractor prepares lists of approved parts and materials for use by his design engineers. These lists are submitted to NASA MSC for review. The approved parts and materials are based on studies and qualification tests.

As a general policy, the contractor selects parts and materials for the TAPLE assembly based on proven qualification and selects the parts and materials from subcontractors and vendors employing effective reliability and quality programs in their manufacture. First priority is given to items previously qualified to pertinent specifications with particular emphasis on currentness of data, qualification applicability, and adequacy of specifications.

For parts and materials without adequate specifications for TAPLE application (as jointly determined by the contractor and NASA), the contractor prepares the required specifications. Each specification includes requirements for the applicable reliability and mission criteria. Protective packaging requirements are included in each specification where applicable. Each specification is available for NASA MSC review.

For parts and materials without adequate qualification data, the contractor designs and conducts qualification tests. These tests determine the adequacy of the parts and materials in meeting the TAPLE assembly specification requirements and are used to develop criteria for acceptance testing. All such proposed test specifications are submitted for NASA MSC review. The contractor submits monthly reports on the status of the qualification tests. Items requiring changes after initial qualification require requalification to assure control.

4.3.10.2 Parts and Materials Application Review

Prior to the final design acceptance of each component (black box), the contractor or subcontractor, if appropriate, conducts a thorough applications review to determine the applicability of each part and materials (or design features) on that design to mission profile requirements (including environments). These reviews are thoroughly documented and are considered a check list for formal design reviews. Documentation is available within 30 days completion of each review, for review by NASA MSC. The contractor, however, takes immediate action to correct any deficiencies.

4.3.11 EQUIPMENT LOGS

The contractor maintains a separate log for each major component and subsystem of the TAPLE assembly. These logs are maintained

throughout all phases of the program. Each log is identified to the equipment to which it pertains, is maintained in chronological order, and accounts for all periods of time including idle periods and any movements of the item. Complete self-explanatory entries include, but are not limited to the following: (a) date and time of entry, (b) identity of test or inspection, (c) environmental conditions, (d) characteristics being investigated, (e) parameter measurements, (f) complete identification of instrumentation used including serial number and calibration data, (g) failure observations and failure report reference, (h) accumulated operating time, (i) cumulative number of duty cycles to date, (j) discrepancies between the item tested and pertinent specifications or drawings, (k) repair and maintenance record, (l) record of pertinent, unusual, or questionable occurrences involving the equipment, (m) action taken to have "quick fixes" formalized as design changes, and (n) identity of individual making entry.

The contractor submits a proposed format for equipment logs for approval by NASA MSC or includes this information as a part of the reliability program plan. If the proposed format is presented in the quality assurance plan, the appropriate paragraphs need only be referenced in the reliability program plan. The equipment logs are not necessarily submitted to NASA MSC but are available at all times for review.

4.4 TESTING AND RELIABILITY EVALUATION

The contractor develops a reliability evaluation program for application throughout the TAPLE assembly program. The evaluation program obtains data required to determine the degree of assembly performance in terms of the contractual requirements of 3.1.2.1, Specification SY1-11. The contractor's reliability organization is responsible for providing reliability test inputs to the overall integration plan to assure maximum reliability evaluation at the system, subsystem, and component levels.

4.4.1 RELIABILITY EVALUATION PLAN

As a separate section of the reliability program plan, the contractor submits a reliability evaluation plan. This plan includes outline

and schedule of the integrated testing for the Phase I Test/Verification, 4.1 of Specification SY1-11. The plan also shows the relation to the reliability assessment models and assessment schedule. The reliability evaluation plan:

a) Includes all tests of 4.1, Specification SY1-11.

b) Describes the role of each test in the system reliability evaluation and outlines alternate actions that may be taken as a result of each test.

c) Shows the requirement for various types and degrees of testing based on the reliability prediction and assessment models.

d) Describes the planned use of the test data in confirming or adjusting the assessment models and in the determination of quantative TAPLE assembly reliability.

4.4.2 TESTING

The contractor's integrated test program is designed to evaluate all aspects of the performance capability of the TAPLE assembly and includes evaluation of reliability throughout the Phase I Test/Verification. The contractor's reliability group reviews all test plans and schedules for completeness and assures that all factors which could affect reliability have been considered.

4.4.2.1 Concept of Testing

In general, testing assesses the performance capability of the hardware, potential failures which are not revealed in design reviews and reliability analyses, and provides failure rates and other numerical reliability data. Tests use statistical design of experiment techniques where practical. Tests are conducted under levels of environmental stress and for periods of time as specified in Tables 1 and 2 of Specification SY1-11.

4.4.2.2 Test Specifications, Procedures, and Reports

The contractor prepares a separate test specification, test procedure, and test report for each test in the Phase I, Test/Verification, and reviews and approves those generated as a part of programs of

subcontractors and suppliers. All test specifications and procedures are subjected to NASA MSC review. As a minimum, these documents contain:

a) Test specifications which state test objectives, the test item, number of items to be tested, environmental and performance conditions, testing duration or cycles, allowable maintenance, logging requirements, method of analysis and utilization of test results, disposition of test items, retest requirements, reliability objectives, allowable failures per test and definition of failure.

b) Test procedures which prescribe steps to be accomplished in detail and sequence, test equipment to be used and calibration requirements, layout and interconnection of equipment, and safety practices to be observed.

c) Test Reports which reference the test procedure used, which include the pertinent test specification as an appendix, and which satisfy other criteria on content and format as may be prescribed by NASA. Formal reports of each test are issued as early as possible following completion of testing, but preliminary reports of test results are provided to NASA MSC within 10 days of completion of the test (not to be interpreted as completion of reduction of all test data) as prescribed by NASA.

4.4.2.3 Reliability Demonstration Tests

If formal reliability demonstration tests are required, these will be specified in the contract. The contractor performs reliability demonstration tests (if specified) as agreed to with NASA MSC.

4.4.3 RELIABILITY ASSESSMENT

At specified milestones in the reliability evaluation plan, the contractor verifies the reliability specified in 3.1.2.1 of Specification SY1-11 by analytical studies based on the results of all applicable tests. The contractor performs assessments of the TAPLE assembly reliability by revising failure mode and criticality analyses and updating his reliability models. Applicable data from the contractor's previous programs may also be factored into the analytical studies.

4.4.4 RELIABILITY EVALUATION PROGRAM REVIEW

At major milestones scheduled in the reliability evaluation plan, the contractor and NASA MSC jointly conduct formal documented reviews. In these reviews all pertinent test results are critically examined to determine the need for revisions to the reliability evaluation program and to confirm that those portions of the program under review have adequately evaluated the conformance of the pertinent elements to the apportioned goals. Within 30 days following each review, the contractor furnishes to NASA MSC, for approval, a formal report of the review.

4.5 DOCUMENTATION OF RELIABILITY

The contractor's reliability effort is documented in detail throughout the program and is available for review by NASA MSC and its designated representatives. A central data center is maintained within the contractor's facility. Certain portions of the reliability data generated may be required as inputs to various data exchange programs. Where documentation covers other areas of the program, the documentation is composed only once. To satisfy reliability documentation requirements, the contractor need submit only copies of these items (e.g., test specifications). Specific documentation is as prescribed in the contract.

4.5.1 RELIABILITY PROGRESS REPORT

4.5.1.1 Periodic Progress Reports

The progress of the reliability program and each task is reported on the same schedule as that required on the contract for overall technical progress. The reliability report may be submitted as a separate section of the regular periodic progress report and would include the following information on the contractors' and subcontractors' programs:

a) Technical progress of the reliability program including significant accomplishments and milestones reached,

b) Reliability problem areas and anticipated reliability program slippages and their effects,

c) Revised schedules for work and significant program events in the succeeding reporting period,

d) Significant decisions and actions having impact on the reliability effort and their effects on the program,

e) Pertinent technical data, reports, and summaries.

4.5.1.2 Reliability Program Control Reports

The contractor submits reliability program control reports as a separate section of the periodic financial and management reports required by the contract. This includes cost and expenditure data for the reporting period, as well as estimates for the succeeding period in accordance with 5.1.1.

5.0 INTEGRATION PLAN

5.1 INTRODUCTION

The integration plan presents the methods to be used for final assembly, integration, and performance checks of the TAPLE assembly prior to environmental tests. It covers the operations performed on TAPLE subassemblies from time of receipt in the integration area until a completely integrated TAPLE assembly is ready for environmental testing.

The plan calls for the receipt of all subassembly units at the beginning of the assembly sequence in order to prevent schedule delays. The subassembly units will have been previously tested and qualified as individual components prior to receipt in the integration area.

The testing of all TAPLE assemblies is performed as outlined in this plan with one set of EGSE. The plan as outlined requires no special handling fixtures or equipment for the assembly and integration process.

5.2 INTEGRATION SEQUENCE

The flow diagram in Figure 3 illustrates the complete assembly and integration sequence. Detailed definition of the operations is presented in Section 5.3.

The integration sequence begins with receipt of the basic TAPLE structure assembly, interconnection harness, and all subassembly units in the integration area. Upon receipt of these units, a log book and routing and operation (R and O) cards are established. The log book is used to maintain a history of all integration and test operations to which the TAPLE assembly is subjected. The R and O cards are used to route and control each subassembly and the TAPLE assembly through each of the integration and test operations.

Upon receipt, each subassembly is inspected for workmanship.

The first operations of the integration sequence begin with the inspection and assembly of the basic TAPLE housing. The interconnection harness and temperature sensors are then installed and fastened within the structure. Since subassembly units will not have been installed at this time, wooden mockups are used to insure proper routing and clearance of the harness.

The first subassembly to be installed is the power conditioner unit (PCU). Following PCU installation and prior to connecting the electrical harness to it, the harness is subjected to a continuity and hi-pot test. The harness is then connected to the PCU and a test for proper distribution of power is made. In parallel with these integration operations, the other subassembly units are subjected to system simulator tests.

After completion of simulator tests all remaining subassembly units are installed and connected to the harness. A fuse box is inserted in series in all output power lines of the PCU and system operation is checked. The VSWR and RF system tests and calibrations are made and are followed by a power profile determination.

Calibration curves on each channel of the telemetry system are made prior to the first integrated systems test (IST). The IST is a complete electrical check of the TAPLE assembly utilizing all command signals and data lines with TAPLE in each of its modes of operation.

Following the IST, the thermal control components are installed and the electromagnetic interference test is performed. After the mass properties of the package are determined, another IST is conducted as a final test and buy-off of the assembly and integration operations. The unit is then ready for delivery to the environmental test area for qualification tests.

5.3 DETAILED INTEGRATION OPERATIONS

The following is a detailed definition of the assembly and integration operations. Operation numbers are keyed to the numbers within the small circles above each operation on the flow diagram in Figure 3.

(1) Structural Assembly Receipt and Inspection

Purpose of Operation

To receive, inspect, and prepare the structure assembly for installation and integration of the TAPLE subassemblies.

Description of Operation

The structure is received in a semi-assembled condition. The component mounting shelf is mounted to the housing and all other mounting hardware and fasteners are supplied. The

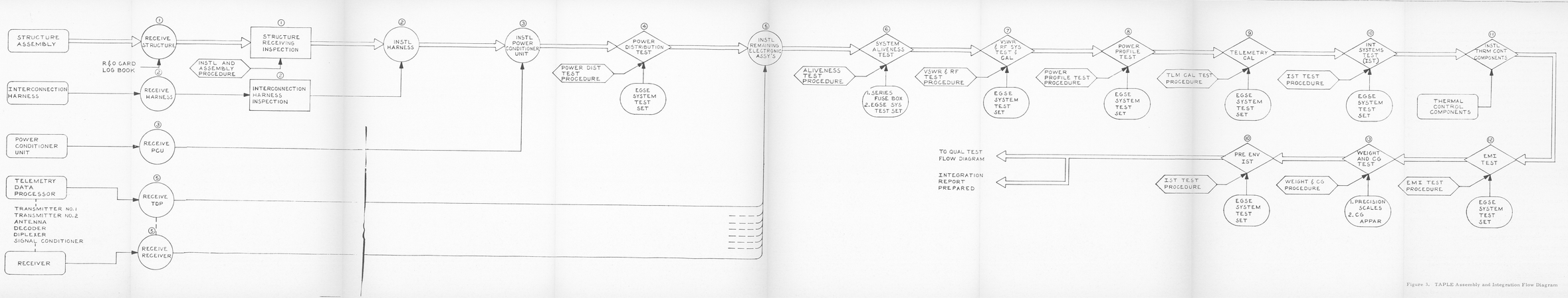

Figure 3. TAPLE Assembly and Integration Flow Diagram

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thermal control louvers and external Mylar insulation are not assembled at this time. The structure assembly is inspected for compliance with all requirements of the design specification. Dimensions, form factor, weight, nameplate information, and quality of workmanship are verified.

Equipment and Procedures Required

- Installation and assembly procedure
- TAPLE assembly drawings
- Log book
- R and O card
- Mechanics tool kit
- Precision scales

(2) Harness Installation and Test

Purpose of Operation

To receive, inspect, and install the electrical interconnection harness and temperature sensors.

Description of Operation

The interconnection harness is inspected for quality of workmanship and proper identification. The harness is then installed in the structure and all cable clamps and fastening hardware are secured. Wooden mockups of the assemblies with dummy connectors are used in the structure to ensure proper routing and dressing of the harness. All temperature sensors are routed and secured to the structure assembly.

Equipment and Procedures Required

- Installation and assembly procedure
- TAPLE assembly drawings
- Interconnection harness wiring diagram
- Log Book
- R and O Card
- Wooden mockups of TAPLE subassemblies
- Mechanics tool kit

(3) Installation of Power Conditioner Unit

Purpose of Operation

To receive, inspect, test, and install the power conditioner unit (PCU) in the TAPLE housing.

Description of Operation

The PCU is inspected upon receipt for quality of workmanship, dimensions, weight, and identification. Upon satisfactory completion of this inspection, the PCU is installed in the housing.

Equipment and Procedures Required

- Simulator test procedure
- Installation and assembly procedure
- TAPLE assembly drawings
- Log book
- R and O card
- System simulator
- Mechanics tool kit
- Precision scales
- Oscilloscope
- Volt-ohm-milliammeter

(4) Power Distribution Test

Purpose of Operation

To verify correct routing of interconnection harness and proper distribution of power.

Description of Operation

Prior to connecting the harness to the PCU, a complete continuity and hi-pot test of the harness is performed. The harness is then mated to the PCU and the proper distribution, amplitude, and polarity of all power verified using the power supply simulator of the EGSE system test set.

Equipment and Procedures Required

- Power distribution test procedure
- Interconnection harness wiring diagram
- Log book
- R and O card
- EGSE system test set
- Hy-pot tester
- Continuity tester
- Volt-ohm milliammeter
- Mechanics tool kit

(5) Installation of Electronic Subassemblies

Purpose of Operation

To receive, inspect, test, and install the following subassemblies: transmitter No. 1, transmitter No. 2, antenna, command decoder, diplexer, telemetry data processor (PCM encoders No. 1 and No. 2 and the data storage unit), signal conditioner, and receiver.

Description of Operation

Each of the above listed subassemblies are inspected upon receipt for quality of workmanship, dimensions, weight, and identification. Upon satisfactory completion of the inspection, all units are installed on the housing.

Equipment and Procedures Required

- Installation and assembly procedure
- Simulator test procedure
- TAPLE assembly drawings
- Log book
- R and O card
- System simulator
- Mechanics tool kit
- Precision scale
- Oscilloscope
- Volt-ohm-milliammeter

(6) System Aliveness Test

Purpose of Operation

To verify the proper electrical installation of each subassembly and the operation of the system.

Description of Operation

This is not planned as a complete system test in which detailed performance is determined. The test verifies that each subassembly is properly connected in the system and that its power consumption is within correct limits. The system is operated using the EGSE system test set. All power delivered from the power conditioner unit is distributed through a series fuse box.

Equipment and Procedures Required

- System aliveness test procedure
- Log book
- R and O card
- EGSE system test set
- Series fuse box

(7) VSWR and RF System Test

Purpose of Operation

(1) To verify that the antenna has been correctly installed and to determine the voltage standing wave ratio.

(2) To determine the RF system operating characteristics.

Description of Operation

The VSWR and insertion loss is determined using a signal generator and a VSWR detector. The receiver, diplexer, command decoder, transmitter, and the RF transmission system are tested and calibrated as a system.

Threshold levels and critical parameters such as the following are determined: receiver gain, command threshold, system noise figure, frequency stability, bandwidths, and

transmitter power. The test is conducted with the EGSE system test set utilizing the RF link.

Equipment and Procedures Required

- VSWR and RF system test procedure
- Log book
- R and O card
- EGSE system test set
- Signal generator
- VSWR detector
- Frequency counter
- RF wattmeter
- Noise and field intensity meter and tuning units
- Oscilloscope
- Miscellaneous couplers, filters, and other RF test equipment

(8) Power Profile Test

Purpose of Operation

To acquire accurate measurements of the TAPLE assembly power loads in each of the operating modes and at various voltage levels.

Description of Operation

Voltage and current measurements are made at the TAPLE assembly interface utilizing the power source simulator and dummy loads to simulate experiments. The TAPLE assembly is operated in each of its operating modes with its voltage input adjusted to three different levels.

Equipment and Procedures Required

- Power profile test procedure
- Log book
- R and O card
- Experiment dummy loads
- EGSE system test set

- Digital voltmeter
- Ammeter
- X-Y plotter

(9) Telemetry Calibration

Purpose of Operation

To perform an end-to-end detailed calibration of each channel of the telemetry system.

Description of Operation

Calibration reference inputs are introduced in each telemetry channel at the experiment interface connector on the TAPLE housing and at the input to the signal conditioner. The acquired data is used to formulate telemetry input/output curves for verification of system parameters.

Output samples are obtained at the output of the telemetry data processor and at the EGSE system test set data display.

Equipment and Procedures Required

- Telemetry calibration procedure
- Log book
- R and O card
- EGSE system test set
- Telemetry calibration equipment
- Digital voltmeter
- Oscilloscope

(10) Integrated Systems Test

Purpose of Operation

To perform an end-to-end system test to demonstrate that the TAPLE assembly meets the performance requirements of the system specification.

Description of Operation

The test is designed to perform an overall check of the TAPLE system in each of its modes of operation. Since actual experiments are not available during conduct of

this test, the experiment simulator in the EGSE system test set (EGSE/STS) provides typical data inputs to the telemetry system. All power to the TAPLE assembly in test is obtained from the power source simulator.

All commands to the TAPLE assembly are transmitted by RF/hardline links from the EGSE/STS. The experiment simulator circuitry determines the presence and electrical characteristics of all signals supplied to the experiments from the TAPLE assembly. Data outputs of the experiment simulator in binary and analog form indicate acceptable/nonacceptable inputs to the experiment simulator.

All data channels, both experiment and housekeeping, of the telemetry data processor are operated in each of its modes, bit rates, and formats. All data is transmitted by RF/hardline links to the EGSE/STS where it is displayed on the data display.

Equipment and Procedures Required

- Integrated systems test procedure
- Log book
- R and O card
- EGSE system test set

(11) Installation of Thermal Control Components

Purpose of Operation

To install thermal control components on the TAPLE housing.

Description of Operation

Installation of the thermal control louvers and the Mylar blanket into the TAPLE housing is deferred until this time in order to prevent damage during previous testing. The thermal control components are installed at this time in order to make a complete flight assembly ready for qualification acceptance testing.

Equipment and Procedures Required

- Installation and assembly procedure
- TAPLE assembly drawings
- Log book
- R and O card
- Mechanics tool kit

(12) Electromagnetic Interface Test

Purpose of Operation

To verify that the TAPLE assembly meets the EMI requirements of the system specification. The test is performed on the prototype only.

Description of Operation

Conducted and radiated interference as well as susceptibility measurements are performed per MIL-1-26600 and MSC-ASPO-EMI-10A. The test attempts to identify and isolate generated interference and to determine susceptibility to extraneous interference. The various modes of operation are simulated during these tests as defined in the EMI test plan.

Equipment and Procedures Required

- EMI test plan
- Log book
- R and O card
- Shielded enclosure
- EGSE system test set
- Noise and field intensity meter, tuning units

(13) Weight and Center of Gravity Test

Purpose of Operation

To determine the mass properties of the TAPLE assembly.

Description of Operation

Weight measurements are made on precision laboratory scales. The center of gravity of the assembly is determined using an apparatus which allows the package to be swung from suspension points.

Equipment and Procedures Required

- Weight and CG test procedure
- Log book
- R and O card
- Precision scales
- CG apparatus

5.4 ASSEMBLY AND INTEGRATION SCHEDULE

The assembly and integration schedule depicted in Figure 4 shows elapsed time in half days for each of the detailed integration operations for the prototype qualification unit. The overall time required for assembly and integration as outlined in this plan is 24 working days. It is expected that assembly and integration time for a typical flight unit could be shortened to approximately 20 working days.

The schedule assumes the availability of all qualified subassembly units at the start of the assembly and integration sequence. The schedule also requires that one complete set of EGSE and test equipment be available during this period.

5.5 TEST PROCEDURES

The assembly and integration of the TAPLE assembly requires the preparation of a number of test procedures. The following information is within the scope of the procedures:

- Instructions and drawings for test preparation and set-up
- Lists of all required test equipment
- Lists of all required reference documents
- List of personnel required for conduct of the test
- Definition of any hazards or precautions associated with the test

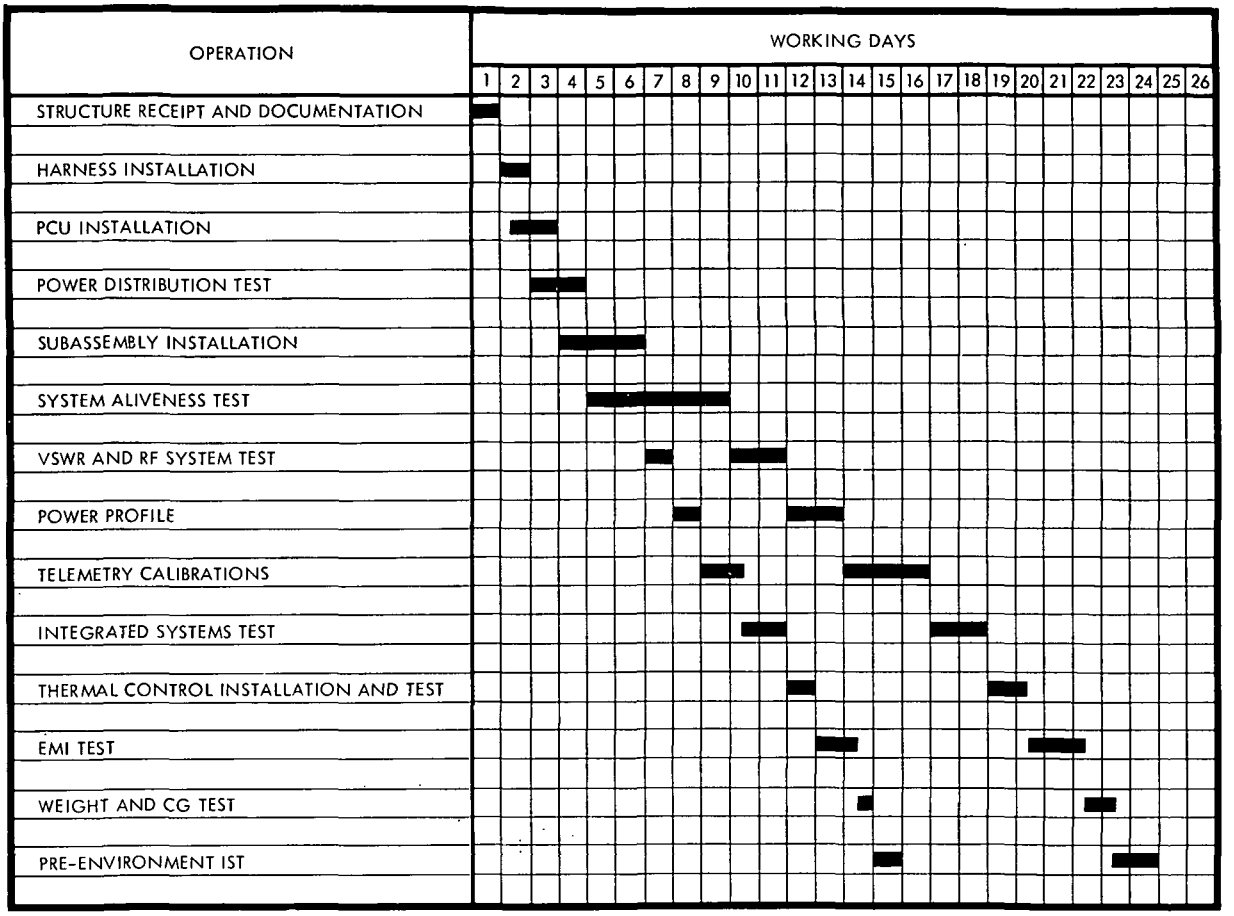
OPERATION
WORKING DAYS
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
STRUCTURE RECEIPT AND DOCUMENTATION
HARNESS INSTALLATION
PCU INSTALLATION
POWER DISTRIBUTION TEST
SUBASSEMBLY INSTALLATION
SYSTEM ALIVENESS TEST
VSWR AND RF SYSTEM TEST
POWER PROFILE
TELEMETRY CALIBRATIONS
INTEGRATED SYSTEMS TEST
THERMAL CONTROL INSTALLATION AND TEST
EMI TEST
WEIGHT AND CG TEST
PRE-ENVIRONMENT IST

Figure 4. Schedule of Assembly and Integration Prototype Qualification Unit

- Detailed step-by-step operations for conduct of the test
- Specific data to be recorded during the test
- A quality control section to record test starting time, equipment operation time, and test verification

The following is a list of the procedures required during the assembly and integration operations:

- Installation and assembly
- Power distribution test
- System aliveness test
- VSWR and RF systems test
- Power profile test
- Telemetry calibrations
- Integrated systems test
- Electromagnetic interference test
- Weight and center of gravity test

5.6 TEST EQUIPMENT

Assembly and integration requires the use of several pieces of specialized test equipment in addition to the normally available and required commercial test equipment. Requirements for the specialized equipment are covered in TAPLE Specification EQ4-168. A listing and brief description of the equipment follows.

EGSE System Test Set

The EGSE/STS contains (1) all necessary equipment required to transmit and receive RF signals to and from the TAPLE assembly, (2) a simulator of the RTG power supply, (3) an experiment simulator which provides data outputs similar to those of actual experiments, (4) an encoder for generating commands, and (5) units for demodulating and displaying data.

TAPLE Subassembly Mockups

Mockups of the TAPLE subassembly units are provided for use in harness routing within the package prior to installation of actual units. The mockups are inexpensive wooden facsimiles of the subassemblies with actual connectors accurately mounted.

Series Fuse Box

The series fuse box used in the system aliveness test consists of a box with connectors for insertion in series with the power conditioner unit output connector. All power distributed from the PCU is routed through easily replaceable fuses on the box.

5.7 TECHNICAL DOCUMENTATION

Two types of technical documentation of integration operations are planned: the log book, for day to day test records, and the integration report for final reporting of integration and test results.

A permanent log book is established at the beginning of the assembly and integration sequence. The log book accompanies the TAPLE assembly through all operations until delivery to the customer. The log, which is maintained by the responsible test engineer, includes integration and test results from all operations to which the package is subjected. Copies of all test data are a part of the log book.

After completion of the pre-environmental integrated systems test, the test results recorded in the log book are reviewed and a formal report summarizing all integration and test operations is prepared.

6.0 QUALIFICATION TEST PLAN

6.1 INTRODUCTION

The TAPLE assembly must demonstrate a capability of surviving the environments which will be encountered during the various phases of the mission. In order to establish this capability, the TAPLE assembly is subjected to a series of environmental tests at environmental exposure levels beyond those expected during all mission phases. These phases are:

- Prelaunch
- Launch, earth orbit, translunar, and lunar
- Lunar descent
- Lunar surface

The prelaunch environment includes all exposures that the equipment is likely to encounter during transportation, handling, and storage prior to installation in the LEM equipment compartment.

It is reasonable to assume that sufficient protection will be afforded to the TAPLE assembly to obviate the need for evaluating the ability of the equipment to withstand environment such as rain, salt spray, sand/dust, and fungus. However, the contractor should demonstrate that the equipment will survive these environments if testing is waived.

6.2 EQUIPMENT TO BE TESTED

One or more (depending on schedule constraints) TAPLE assemblies equivalent in configuration and electrical design to the flight article.

One each of the following TAPLE subassemblies:

PCM encoder	Command decoder
Data storage unit	Power conditioner
Diplexer	Signal conditioner
Antenna	Thermal control subsystem
Transmitter	Housing structure
Command receiver	Interconnecting harness

6.3 FACILITIES

6.3.1 GENERAL

The apparatus used in conducting environmental exposures is to be capable of producing and maintaining the required conditions with the test units installed and operating or nonoperating as defined in the equipment specification. Changes in environmental conditions, from the values specified by the applicable test procedures, are not to exceed the tolerances of paragraph 6.4.1.

6.3.2 STANDARD CONDITIONS

Ambient conditions for conducting assembly functional tests prior to or following environmental exposure are indicated below. These apply unless the equipment is sealed, protected, or otherwise functionally insensitive to variations in temperature and humidity:

a) The temperature is $75^{\circ}F \pm 5^{\circ}F$

b) The relative humidity is the prevailing ambient condition during the performance test

c) The barometric pressure is the prevailing ambient pressure at the time of performance tests. Equipment performance data is corrected to an ambient pressure of 760 millimeters of mercury (mm Hg) as required by the applicable equipment test procedure.

6.4 MEASUREMENTS

6.4.1 TOLERANCES

Except as otherwise specified herein, the maximum allowable tolerances (excluding instrument errors) for environmental conditions are as follows:

a) The tolerance on temperature conditions is $\pm 3^{\circ}F$

b) The tolerance on relative humidity is ±5 percent

c) The tolerance on vibration amplitude (sinusoidal) is ±10 percent

d) The tolerance on vibration frequency is ±2 percent

e) The tolerance on random noise vibration is +6 or -3 decibels on a 50 cycle per second (cps) bandwidth basis.

f) Changes from one temperature condition to another are accomplished at a rate of temperature not to exceed $1^{\circ}F$/minute.

6.5 VACUUM MEASUREMENTS

Vacuum measurements are made utilizing an instrument which is exposed to the same vacuum environment as the test unit, within the limitations of the instrumentation state-of-the-art.

6.6 TESTING SEQUENCE

The TAPLE assembly is to have successfully passed all phases of "production" acceptance testing prior to the initiation of physical testing. Also, the TAPLE subassemblies are to have successfully passed production tests prior to the initiation of the qualification test sequence.

6.7 DESCRIPTION OF TESTS

During the qualification test sequence an abbreviated functional performance test is performed after each environmental test to assess the condition of the TAPLE assembly and/or the subassemblies. The parameters measured are those most likely to be affected by the particular environmental exposure. Vibration exposure consists of both sine and random tests. All temperature tests commence after equipment has stabilized at the specified temperature level. Stabilization is defined as average temperature variation not in excess of $3^{\circ}F$/hour. No temperature changes should be imposed which may produce thermal shock other than that specified in the following test plan.

The test sequences for the TAPLE assembly and the TAPLE subassemblies are shown in Figures 5 and 6, respectively.

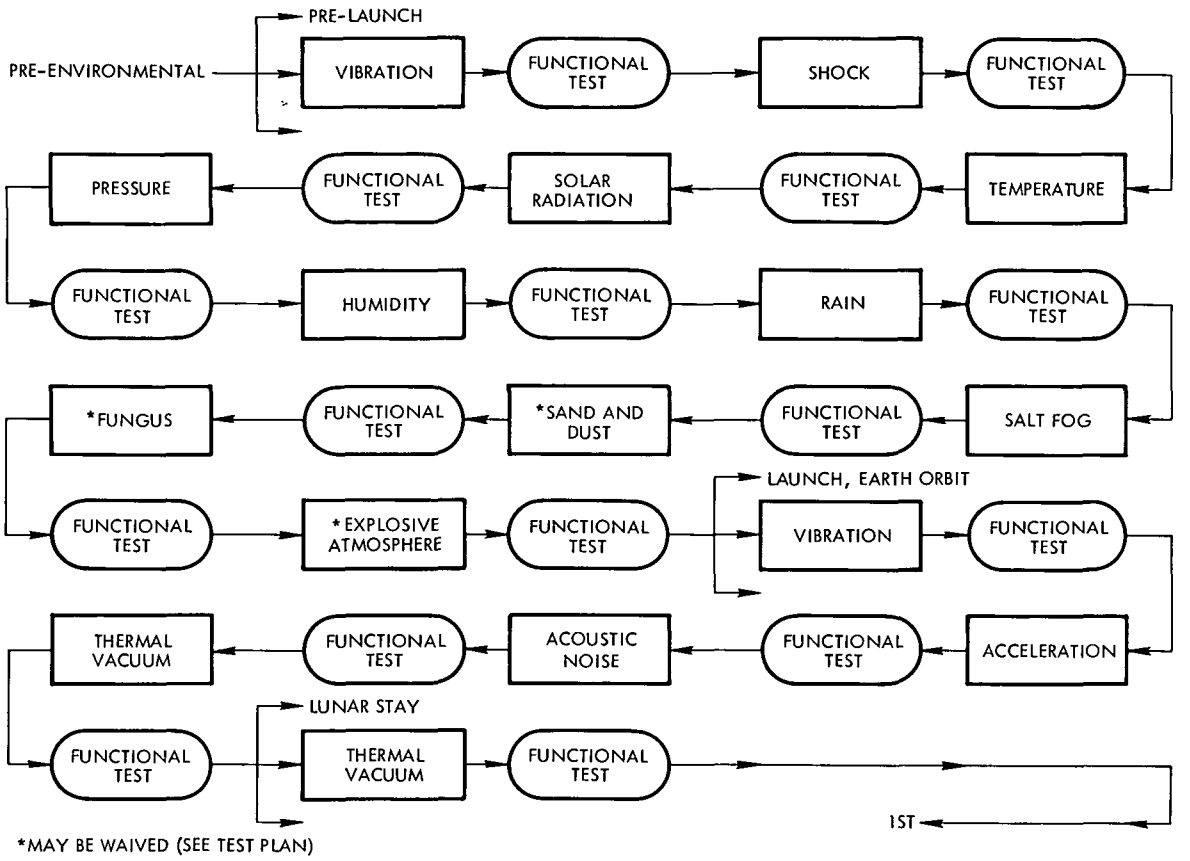

Figure 5. Assembly Qualification Test Sequence

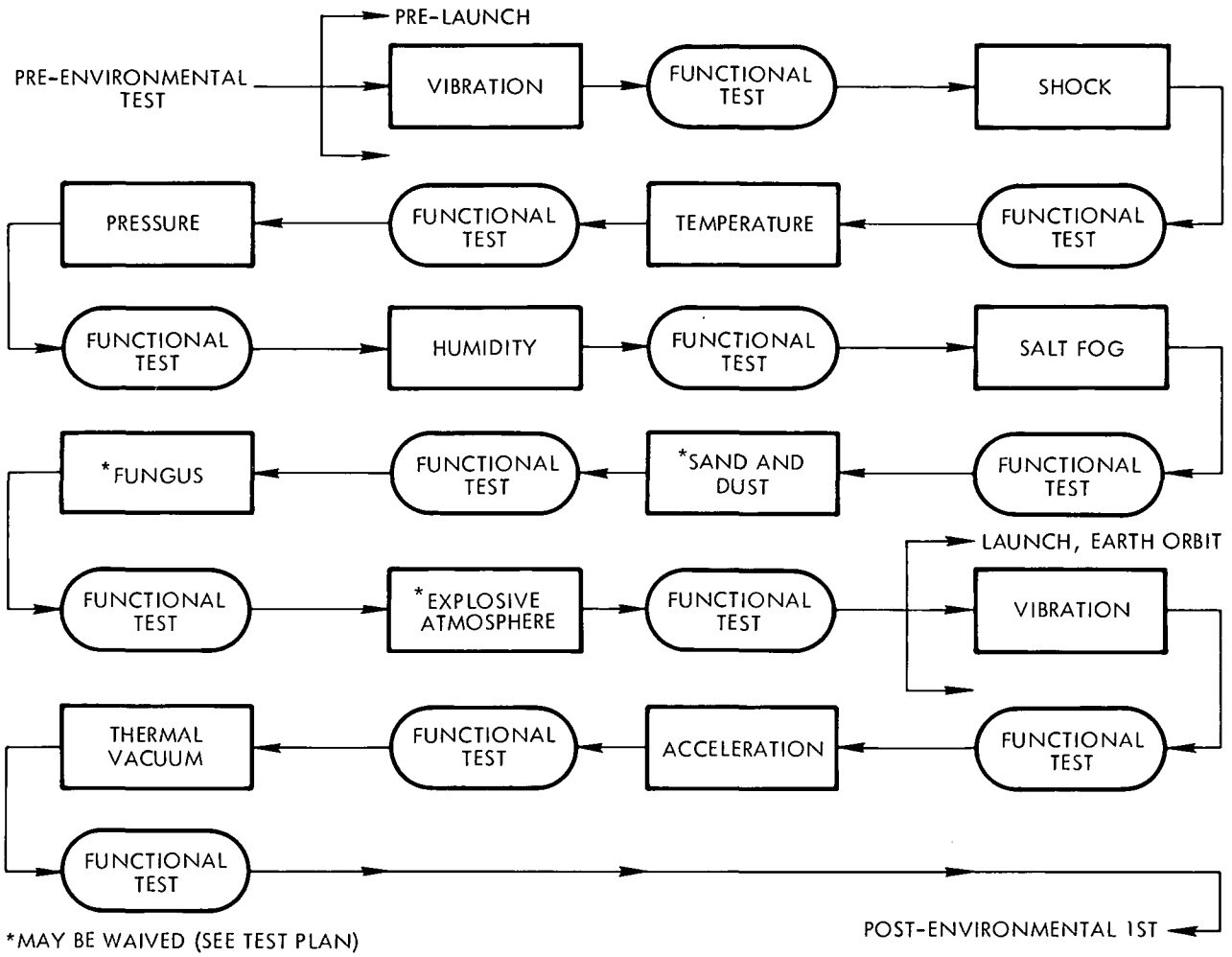

Figure 6. Subassembly Qualification Test Sequence

6.8 DETAILED TEST PLAN

6.8.1 PRELAUNCH (EQUIPMENT NONOPERATING)

6.8.1.1 Vibration

The TAPLE assembly is attached to a vibration exciter simulating the means by which it is mounted within its shipping container.

The subassemblies are mounted in a manner simulating attachment to the assembly. The levels and durations of exposure are as follows:

Sinusoidal Vibration

5 - 7.2 cps	0.5 in DA
7.2 - 26 cps	±1.3 g
26 - 52 cps	0.036 DA
52 - 500 cps	±5.0 g

The sinusoidal sweep rate is 1/2 octave/minute. The unit is subjected to one sweep (5 cps to 500 cps) in each of three mutually perpendicular axes.

Random Vibration

10 - 28 cps	0.18 g^2/cps constant
28 - 37 cps	12 db/octave decrease
37 - 100 cps	0.059 g^2/cps constant
100 - 1200 cps	12 db/octave decrease
1200 - 2000 cps	0.031 g^2/cps constant

Random vibration exposure duration is 30 minutes per axis.

6.8.1.2 Shock (Unpackaged)

Machine Shock - Per MIL-STD-810, Method 516, procedure I, modified. Modify shock pulse to sawtooth 15 g peak 10 to 12 msec rise, 0 to 2 msec decay

Drop Test (Packaged-Applicable to TAPLE assembly only) Per MIL-STD-810, Method 516, Procedure III.

6.8.1.3 Acceleration (Not applicable)

6.8.1.4 Temperature (Packaged)

Low Temperature

The unit is placed in a temperature chamber and the temperature stabilized at -65°F and maintained at this level for a period of not less than 12 hours. The chamber temperature is then returned to ambient and performance verified. (Rate of change of temperature should not exceed 1 deg/min.)

High Temperature

The unit is placed in a temperature chamber. The temperature is stabilized at +160°F and maintained at this level for a period of not less than 12 hours. At the completion of this exposure, the chamber temperature is gradually returned to ambient. (Rate of change of temperature is not to exceed 1 deg/min.) The performance is verified by performing a functional test.

6.8.1.5 Solar Radiation (Applicable to TAPLE assembly only)

The unit is placed in a temperature chamber and stabilized at -20°F. The unit is exposed to thermal radiation of 360 Btu/ft^2/hr for a period of 6 hours.

The chamber temperature is then raised to 110°F and the unit again exposed to thermal radiation of 360 Btu/ft^2/hr for a period of 6 hours.

6.8.1.6 Pressure

The unit is placed in a vacuum chamber. With the temperature uncontrolled, the pressure is reduced to an equivalent of 50,000 feet. The pressure is maintained at this level for a period of not less than 8 hours. The pressure is returned to ambient and the performance verified by means of a functional test.

6.8.1.7 Humidity

The unit is subjected to humidity tests as specified in MIL-STD-810, Method 507. Total exposure time is 240 hours.

6.8.1.8 Rain* (Applicable to TAPLE assembly only)

The unit in the packaged condition is subjected to a rain test as defined in MIL-STD-810, Method 506.

6.8.1.9 Salt Fog*

The unit in the unpackaged condition is subjected to a salt fog test as described in MIL-STD-810.

6.8.1.10 Sand and Dust*

The unit in the unpackaged condition is subjected to a sand and dust test as specified in MIL-STD-810, Method 510 with the length of exposure reduced to 4 hours and the temperature maintained at 77°F.

6.8.1.11 Fungus*

The unit in the unpackaged condition is subjected to a fungus test as specified in MIL-STD-810, Method 508, Procedure I.

6.8.1.12 Explosive Atmosphere

The unit in the unpackaged condition is subjected to an explosion test as defined in MIL STD-810, Method 511, Procedure I.

6.8.2 LAUNCH, EARTH ORBIT, TRANSLUNAR AND LUNAR ORBIT (EQUIPMENT NONOPERATING)

6.8.2.1 Vibration

The unit is attached to the vibration exciter utilizing a fixture which simulates the manner in which it attaches to the LEM or assembly structure. The vibration is monitored at the attachment points.

The vibration (sine and random) is imposed sequentially in each of three mutually perpendicular axes to the following stress levels:

*May be waived with sufficient justification

Sine Vibration Schedule

cps	Displacement or Accel
5.0 - 7.2	0.5 in DA
7.2 - 11.2	1.3 g's
11.2 - 18.5	0.2 in DA
18.5 - 44	3.5 g
44 - 52	0.035 in DA
52 - 128	5.0 g's
128 - 140	0.006 DA
140 - 310	6.0 g's
310 - 425	0.0012 in DA
425 - 2000	11.0 g's

Random Vibration Density

10 - 20 cps	12 db/octave rise to
20 - 85 cps	0.052 g^2/cps
85 - 100 cps	12/db/octave rise to
100 - 1000 cps	0.10 g^2/cps
1000 - 1200 cps	12 db/octave roll off
1200 - 2000 cps	0.052 g^2/cps

The sweep rate for the sine vibration is logarithmically at one-half octave/minute from 5 to 2000 cps for 2 sweeps.

6.8.2.2 Acceleration

The unit mounted to a centrifuge in a manner simulating the means used to attach it to the LEM and subjected to accelerations in each direction along each of the three mutually perpendicular axes as follows:

x axes - 5.0 g's for 17 minutes
y axes - ±0.75 g's for 17 minutes
z axes - ±0.75 g's for 17 minutes

followed by 7 g's in all directions for 5 minutes duration.

6.8.2.3 Acoustic Noise (Applicable to TAPLE assembly only)

The unit is subjected to an acoustic noise test described in MIL-STD-810, Method 515, Grade B, Table 515-I.

6.8.2.4 Thermal Vacuum

The unit is placed on a heat sink in a thermal vacuum chamber, the temperature stabilized at $0^{o}F$, and the pressure reduced to 1×10^{-5} mm Hg.

After stabilization of the temperature and pressure the conditions are maintained for a period of 12 hours. Upon completion of this exposure the temperature is raised to $160^{o}F$ and maintained for an additional 12 hours.

After completion of the high temperature exposure, the conditions are returned to ambient and a complete functional test performed.

6.8.3 LUNAR DESCENT (EQUIPMENT NONOPERATING)

The qualification of the TAPLE assembly in the lunar descent environment has been verified by the test delineated in prelaunch and earth orbit, translunar, and lunar orbit.

6.8.4 LUNAR STAY (EQUIPMENT OPERATING)

The TAPLE assembly is subjected to a thermal vacuum test. The TAPLE assembly is placed in a thermal vacuum chamber and is thermally isolated from the chamber structure.

Provisions are made to simulate the inputs of the RTG both in physical configuration and thermal load. The chamber must be capable of simulating the thermal input resulting from solar radiation while the surrounding chamber walls are maintained at LN_2 temperature. The sun shield of the TAPLE assembly is exposed to the solar simulator. The base of TAPLE is shielded from the cold wall by means of an isolating surface.

With the assembly operating, the pressure reduced to 1×10^{-5} torr, and the chamber walls stabilized at LN_2 temperature, the assembly complete with sun shield is exposed to solar radiation of approximately 442 $Btu/ft^2/hr$ for a period of 20 hours. During this exposure, the TAPLE assembly is rotated through 180 degrees so that the angle of incidence of "sunlight" on the sun shield changes during the exposure.

After 20 hours, the solar simulator is turned off and the TAPLE assembly subjected to a 10 hour soak at LN_2 temperature. The above constitutes one cycle. The assembly is subjected to six cycles as described above.

6.9 TEST DOCUMENTATION

The contractor provides a complete test report documenting the results of each qualification test sequence performed.

This report is submitted for tests performed on subassemblies as well as on the TAPLE assembly.

The reports are submitted 60 days after the completion of each test and contain, as a minimum, the following information:

1) Summary. A brief resume of the test results indicating predominant conclusions.

2) Test results including a copy of the raw data and any analysis required for data reduction.

3) All charts, photographs, and recordings comprising the raw data.

4) A brief discussion of results relating the test information to the requirements outlined in the design specification.

5) Conclusions drawn from test results and data analysis. The section includes description of all anomalies which occurred during test and possible implication of effect on system performance.

7.0 MANUFACTURING PLAN

7.1 GENERAL

A detailed manufacturing plan is presented in which each subassembly of TAPLE is identified, the method of acquisition explained, and the flow through the manufacturing organization illustrated.

The TAPLE manufacturing plan is based on a group of tasks culminating with the delivery of flight hardware. One assembly of this hardware consists of:

Description	Quantity
Data storage unit	1
PCM encoder	2
Signal conditioner	1
Transmitter	2
Command decoder	1
Command receiver	1
DC converter	1
Diplexer	1
Antenna	1
Thermal control	1
Housing structure	1
Interconnecting harness	1

7.2 MANUFACTURING TASKS

7.2.1 MAKE-OR-BUY

In determining whether an item should be subcontracted, procured, or fabricated in-house, the contractor's evaluation considers:

a) The effect of make-or-buy decision on price, quality, delivery, and performance.

b) The effect of make-or-buy or subcontract on the contractor's plans to broaden the subcontractor base through competition.

c) The competence, ability, experience, and capacities available within subcontractor organizations.

d) The impact of the make-or-buy decisions on the contractor's policy of offering to small business concerns an equitable opportunity to compete for subcontracts.

e) The determination of whether an item concerned imposes a significant change in the contractor's and the subcontractor's normal in-plant operations.

f) Whether an item has been subcontracted previously.

g) Other significant factors such as future requirements, tooling, starting costs, and the availability of qualified personnel.

7.2.2 MANUFACTURING PROCEDURES

The contractor conducts qualification and acceptance testing of all TAPLE assemblies. All flight type equipment is tested both as assemblies and as individual subassemblies. These tests and the subsequent production program are implemented by a high quality fabrication and assembly operation in which reliability, quality control, and manufacturing control are stressed. Fabrication is in strict accordance with drawings and specifications. Modern facilities and advanced planning, scheduling, and production control techniques developed for space hardware production are used for both mechanical and electronic manufacturing.

7.2.3 DETAIL MANUFACTURING TASKS

The detail manufacturing tasks which the contractor performs are:

a) Planning and scheduling of production
b) Design operations review for manufacturability
c) Application of developed fabrication techniques and production processes
d) Design of tooling
e) Procurement or fabrication of tooling
f) Control of tooling
g) Preparation of operation sheets (master job orders)
h) Preparation of parts accumulation lists
i) Requisition of material and components
j) Procurement of material and components. (The manufacturing and assembly phase of TAPLE overlaps the design phase in the area of procurement of long-lead-time items, tool design, and production planning

k) Receiving and handling of material and components

l) Storage of components, material, and finished items

m) Issue of parts kits and maintenance of lot identity of components in assemblies

n) Provision of personnel for performance of electronic fabrication and assembly tasks

7.3 ORGANIZATION, PROCEDURES, AND CONTROLS

The contractor operates under procedures and controls that ensure product conformance to engineering specifications, schedules, and budgets. To this end the manufacturing and assembly activities on TAPLE are monitored by a subsystem manufacturing engineer. Planning, procurement, and production coordination functions are directed by a production engineer who should be concerned only with the TAPLE program. The contractor provides a manufacturing organization chart, illustrating the operational status of these two important control points. Furthermore, the assembly operations are performed in a restricted access area. This area is dust, temperature, and humidity controlled. These operations are implemented by personnel who are trained and experienced in the manufacture and assembly of units which are similar to TAPLE. The contractor illustrates schematically the normal flow of paper work and hardware.

From the manufacturing viewpoint, implementation starts with contract go-ahead. The subsystem manufacturing engineer meets with engineering and project office personnel to firm up a master schedule covering both engineering and fabrication. The subsystem manufacturing engineer has the responsibility of master scheduling. He is responsible to and represents management in the execution of program schedule obligations and keeps management advised of all aspects of production. Management's responsibility is to react promptly and effectively to deviations in production performance. After appropriate design review, advance material releases are sent by engineering to the production engineer, who directs material planning and controls procurement of long lead-time items.

Upon receipt of work authorizations and production prints, the production engineer, through a production planner, plans the operations, the tooling required, the operations sequence, and the production processing. At this time quality control establishes the required inspection points, which are listed in the production sequence on the master shop order. The planner then prepares a parts accumulation list and a master shop order. The master shop order shows:

- Production operations by department and work station
- Operations sequence and standard shop operation numbers
- Tooling required
- MIL and process specifications
- Inspection points, as determined by quality control
- Production and/or environmental testing required, and the related test specification
- Parts identification instructions
- Packaging or protective covering instructions
- Next assembly
- Stores point

A copy of the parts accumulation list is forwarded to material planning. Material planning reviews the parts accumulation list and determines the material and/or parts needed and those that are on order. Where procurement must be initiated, a purchase requisition is prepared and forwarded to purchasing. Following purchasing action, a copy of the purchase order and a copy of the purchase requisition is returned to material planning for use as a follow-up against the promised delivery date.

Material and parts are received and checked by the receiving department for damage, proper content, and quality against the purchase order and packing slip. A "flash" copy of the receiving paper (receiving) is forwarded to material planning as notification of arrival; the material is then moved to receiving inspection, along with travel copies.

Receiving inspection inspects material/parts against the related prints/specifications, confirms receipt of process, material, and conformance certifications, along with test reports when they have been made a part of the purchase order contract. Raw material is color-coded in

accordance with quality control identification requirements. Following inspection, the acceptable items are forwarded to work-in-process stores, where the stores supervisor signs for receipt. Items not acceptable are retained by receiving inspection until purchasing advises disposition.

The contractor provides a fabrication stores for raw material and a work-in-process stores for parts and material awaiting initial release to production or awaiting further production operations. These are storerooms with access limited to responsible production planning and control and quality control personnel. They are under the direct surveillance of quality control and are periodically audited. They are maintained and operated by fabrication material control. Parts and materials are released to production only by properly authorized paperwork such as a parts accumulation list, material requisition, or a parts failure report.

Upon receipt in fabrication stores, parts and materials are checked for correct quantity. A bin card is prepared showing the:

- Date of receipt and quantity
- Receiver number
- Description and part number
- Supplier lot number and the contract number

Fabrication stores signs the receiver (indicating receipt of the quantity noted) and forwards it to fabrication material control. Fabrication material control posts the accepted quantity shown on the receiver to an inventory record card. The item(s) received from receiving inspection or from work-in-progress stores is handled, packaged (in accordance with contract requirements), and stored completely segregated by contract, awaiting release to production by fabrication material control.

Parts and materials are released initially from fabrication stores to production in kits on a parts accumulation list by fabrication material control. Subsequent requirements are authorized by a material requisition or a parts replacement requisition prepared and requested by production supervision and approved by the production engineer or his delegated alternate in fabrication material control. The need for this type of release can develop from part loss or part rejection in the production cycle; however, each requisition notes and justifies the reason for the request.

Material requisitions for additional parts as a result of lost parts are approved by the department manager.

The functional flow of the parts, components, and materials required for building and testing the subassemblies and the assemblies are shown in a flow diagram. Typical flow diagrams are provided at a detail level. To avoid duplication, only one flow diagram is illustrated where essentially identical flows exist. Figure 8 illustrates a typical flow chart.

During the production cycle, parts are made, assembled, and inspected as noted on the master shop order and forwarded through environmental test (as necessary) to finished goods stores. When parts or units are rejected, they are processed through preliminary review and, when necessary, through the material review board in accordance with quality control procedures. The rejected parts/units remain in quality control custody until disposition has been made.

Requests for drawing changes to improve manufacturability or other reasons originating in the fabrication department are processed through the production engineer to engineering as a "drawing change request." Upon approval, the production engineer makes the necessary changes to the master shop order. Other engineering changes released by the engineering department are also forwarded to the production engineer for incorporation in the master shop order.

Finished goods stores is a controlled access storeroom where completed assemblies and end units are routed on the final assembly master shop order after quality control acceptance. Finished goods stores is subject to quality control audit to assure that items are stored and records are maintained in accordance with contract requirements.

Units completed by production and accepted by quality control are held in finished goods stores awaiting integration and test. They are released for integration and test, identified by a master shop order, and placed under quality control surveillance until returned to finished goods stores for forwarding to shipping in accordance with contract requirements.

The reports issued by the production coordinator are used as his working documents and are also used by various echelons of management to determine the exact status of any particular item in the production cycle;

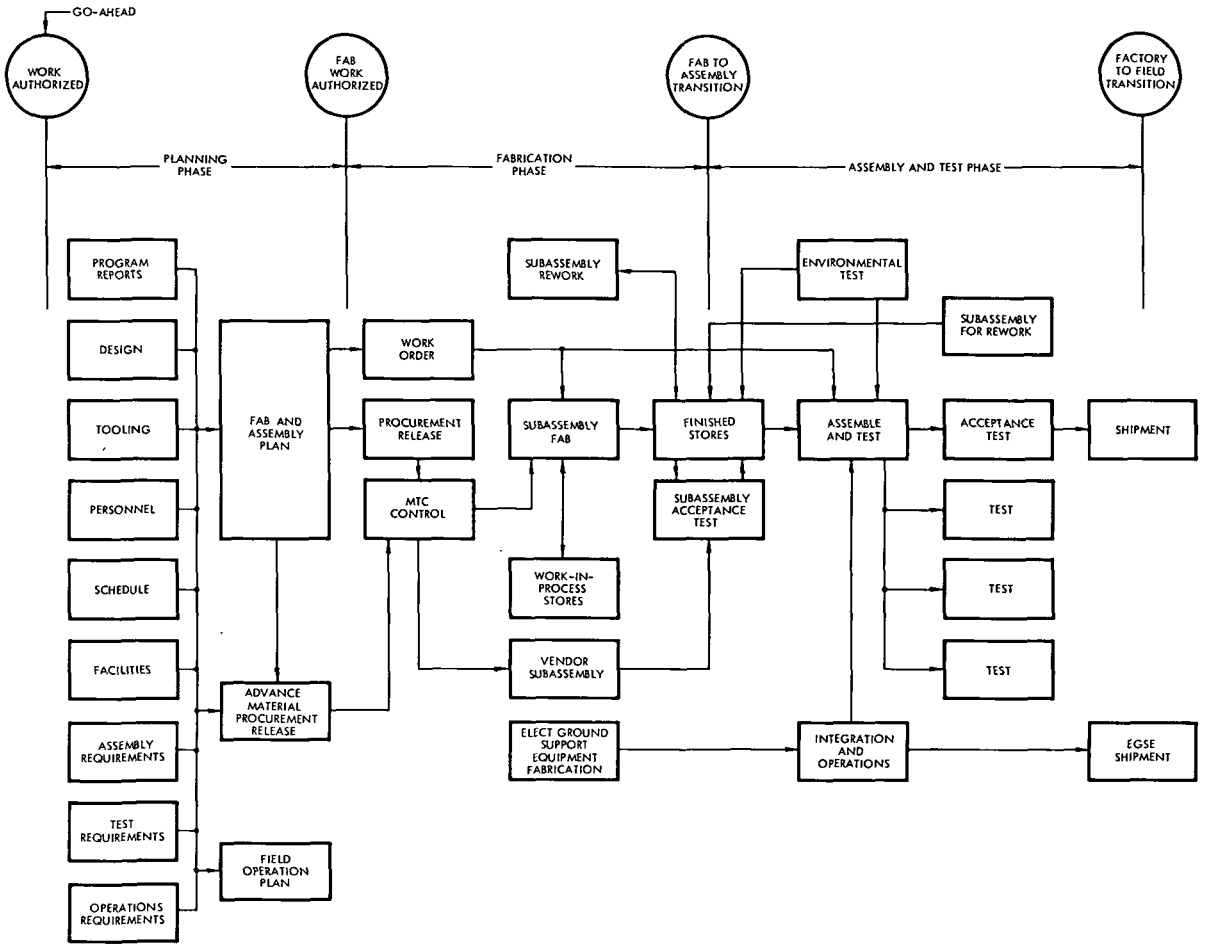

Figure 7. Phase Chart for a Typical Electronic Subassembly

where necessary, these reports are used as a basis upon which to take immediate action to expedite the solution of or to alleviate problems.

7.4 TOOLING

7.4.1 TOOLING POLICY

Generally, TAPLE fabrication and assembly work can be done using general purpose tools and equipment. Special purpose jigs, fixtures, and equipment are provided only in those cases where they are necessary to control configuration, perform an operation, or are specifically required by the TAPLE specifications. The tooling should be as simple, economical, and easy to handle and store as possible, consistent with technical requirements. Typical tooling requirements should be noted on the unit flow diagrams.

7.4.2 TOOLING INSPECTION

All special tooling required for the TAPLE program is inspected and accepted by the contractor's quality control. As a part of the quality control acceptance, the first piece of hardware built using the tooling is inspected and after first piece acceptance the tooling is certified for use, identified, and stamped. When engineering changes necessitate changes in the special tooling, the updated tooling is again accepted for use by quality control. This acceptance is based on reinspection and proofing necessary to ensure that the updated tooling can produce the required hardware.

7.4.3 TOOLING CONTROL

All special tooling is identified in accordance with the contractor's procedures. The accepted tooling is stored and issued to production on a charge-out basis, in accord with production schedules. Tooling is withdrawn by authority of the production engineer or quality control for updating, inspection, or repair. A record card is maintained for each special tool indicating part number, date of receipt, date of issue, and configuration history. When a special tool becomes obsolete or is no longer required, it is disposed of in accordance with the contractor's standard practices.

8.0 QUALITY CONTROL PLAN

8.1 INTRODUCTION

The contractor maintains a quality assurance organization oriented to an effective and timely control of materials, products, and services from all phases of manufacture and test through end item delivery. This organization establishes and maintains controls for all project phases wherein quality is a factor to insure that deliverable end articles for TAPLE conform to NASA MSC prescribed quality standards and technical requirements.

These requirements are established in the statement of work, and the NASA Quality Publication, NPC 200-2. If any differences exist between the statement of work and the NPC 200-2, the statement of work is the governing factor.

The contractor's quality assurance manual establishes company policies, assigns related responsibilities, and provides the necessary procedures for the attainment of product integrity in an economical manner. A description of the quality inspection system is summarized herein.

The personnel administering and performing quality functions are provided with well defined responsibilities and the organizational latitude necessary to insure immediate recognition of problem areas and to initiate expeditious preventative action.

8.2 PROGRAM MANAGEMENT

A senior quality assurance (QA) engineer is assigned within the QA organization to administer and direct in all matters pertaining to insuring quality on the TAPLE program. Other technically qualified personnel from the various functional areas of the contractor's QA organization will work with him to facilitate a timely performance of the quality tasks required for the program.

8.3 DESIGN AND DEVELOPMENT

Specific quality criteria are determined by early review of drawings and specifications, and again during design reviews to ascertain

that methods exist for determining and controlling the quality of items. Controls are established and implemented to ensure that the production of the TAPLE equipment meets specified performance, reliability, and quality requirements.

8.4 INSPECTION SYSTEM

The contractor's inspection system provides for detailed planning of tests and inspections to be performed at suppliers and at the contractors during receiving, manufacturing, and end-item acceptance operations. Inspections and tests are based on a thorough appraisal of individual parts, fabrication, and processing operations to be performed, methods to be employed in assembly and functional test, and test specifications. The characteristics to be inspected or evaluated are clearly defined in the inspection instruction or test procedure relative to nature and tolerance, and to any applicable test conditions such as input, temperature, etc. Documentary evidence of inspections and tests is assured by QA by means of a controlled data collection system.

8.5 PROCUREMENT CONTROL

The contractor's QA invokes the appropriate elements of NPC 200-3 (and other requirements specified by contract) on its suppliers to the extent needed and consistent with program planning for the types of procurement involved. The QA, reliability, engineering, and material organizations at the contractor participate in the selection of procurement sources. Procurement documents are reviewed to ensure that the applicable drawings, specifications, and quality control requirements are specified therein. Quality surveillance is exercised from initial source selection to the completion of the procurement cycle for all purchased articles and services required to satisfy the contractual requirements of the program.

8.6 RECEIVING INSPECTION

Procured articles are inspected at receipt to ensure that they meet the requirements of the purchase order, specifications, drawings, and quality requirements. This inspection assures that:

a) Evidence of the contractor's source inspection (as applicable) accompanies the material

b) Inspection and/or functional tests are completed, are acceptable, and appropriately documented

c) Purchase material is identified and physically segregated as to category: i.e., raw material or finished parts, and inspection status (i.e., awaiting inspection, transfer to stock, or nonconforming material disposition). Finished stock and accepted raw materials are stored in bonded areas subject to effective material control

d) Test reports and certifications (as applicable) are appropriately recorded

e) One-hundred percent inspection of semiconductors received without complete test data is performed

Acceptable items, having been identified with a tag or label, are forwarded to stores with a copy of the receiving report, which identifies to the attendant that the items are acceptable for stock.

8.7 MANUFACTURING CONTROL

Documented criteria for determining design conformance of all articles produced are established for all phases of fabrication and assembly. Inspection stations are located at strategic points to verify product quality. Workmanship standards using pictorial displays and descriptions reflect the optimum acceptable conditions. The design and fabrication of production tooling, jigs, and fixtures are monitored for initial accuracy and repeatability during use. Materials undergoing fabrication or assembly are identified and the inspection status is determined by use of shop travelers using inspection stamps on each operation callout. Cleanliness controls for working areas are established to assure that products fabricated are not affected by dust, improper lubricants, solvents, and chemicals. Use of clean rooms, dust-free wearing apparel, and atmospheric controls are mandatory for delicate assembly applications. Adequate methods and facilities for handling and storage of items are utilized. Special inspections and controls are implemented over special-process operations wherein the finished-article requirements are not readily detectable or measurable. Finished articles are inspected to ensure that applicable design and operational requirements are met.

8.8 END-ITEM INSPECTION AND TEST CONTROL

End-item inspection is concerned with, but not necessarily limited to, those characteristics not inspected previously, a thorough visual inspection of the completed article, and a review of any required supporting documentation. Test inspection requirements are established prior to verification testing. Tests are monitored by QA to ensure that the parameters measured are within tolerance, that the sequence of testing provides a valid measure of overall quality, and that the tests are performed in a manner simulating end use to the highest degree practicable without degradation to the item. Whenever rework or modification of a final tested item occurs, inspection and retesting are accomplished to the extent necessary to ensure quality acceptance.

8.9 INSPECTION STATUS

QA issues, controls, and maintains records of inspection stamps used by the inspection department. Inspection stamps are designed to indicate various degrees of completion, from receiving inspection through fabrication to end-item delivery. The inspection status of all articles is indicated by stamping inspection reports, nonconforming materials reports, test procedures, seals, acceptance/rejection tags, labels, etc. Through the media of inspection records and the inspection stamps appearing on them, traceability is afforded relative to type, time, point of inspection, and the individual inspector.

Documents, records, reports, and other information pertinent to the TAPLE program, which are normal to the quality function and/or specified by contract, are available for review by NASA MSC or his designated representative. Documentation to be provided NASA MSC will be a log book for each flight unit. Each log book contains the following data:

- Operating history of the unit
- References to applicable drawings, specifications, etc.
- Serial numbers and locations of subassemblies
- Complete test records

8.10 INSPECTION MEASURING INSTRUMENT CONTROL

QA maintains a metrology department responsible for the calibration, certification, and maintenance of inspection, test, and measuring equipment. Equipments used for inspection and acceptance tests (e.g., electrical and electronic test equipment, mechanical tools and gauges, etc.) are physically inspected, repaired, calibrated, and certified. A computerized recall system of records and control within this department ensures that measuring equipment is calibrated or certified, or both, at scheduled intervals. Items of equipment are identified by a system of color coding or labels to show the due date of the next calibration. Standards used for the calibration and certification of measuring equipment are traceable to the National Bureau of Standards.

8.11 PROCESS CONTROL

QA establishes and maintains inspections and controls required for special processes. Standards are developed describing the special processes or tests, including preparation, test methods, conditions to be maintained, materials, inspection criteria, and other such control parameters as necessary. Requirements for training and certification of quality inspection personnel are established and maintained in a similar manner.

8.12 NONCONFORMING MATERIAL CONTROL

Nonconforming articles are identified with a rejection tag to prevent their use or delivery to NASA MSC. This control is exercised during receiving, in-process, and end-article inspection and test. The nature of the nonconformance is adequately documented to ensure timely, appropriate corrective action. An initial review is conducted by the assigned QA senior engineer. If the nonconformance is extremely minor and can be reworked to meet drawings, specifications, and workmanship standards, rework to the contractor's standard repair procedures is authorized. If rework is not feasible, a nonconforming material report is prepared and the article and documents are forwarded to the contractor's material review board (MRB) and held in bond pending disposition. (NASA MSC or its designated representative is considered to be an active member of this board.) When location, size, or weight of the article

prevents its being moved to the MRB area, it is clearly identified and set aside from the normal flow pending MRB disposition. In the event the nonconformance is incompatible with contractual requirements, final MRB disposition will rest with NASA MSC.

8.13 CORRECTIVE ACTION CONTROL

The contractor's product assurance department maintains a data collection and analysis system which provides a medium to detect a recurring discrepancy and to initiate swift action for its resolution and correction. Detailed examinations are conducted to determine the nature and cause of a recurring deficiency or failure in order to establish corrective and preventative action. Corrective action requests are initiated for all recurring discrepancies of nonconforming materials either supplier-furnished or contractor fabricated. The senior QA engineer coordinates and follows up all corrective action requests to ensure prompt action and effective resolution.

8.14 DOCUMENT CHANGE CONTROL

The QA system of document change control ensures the following provisions:

a) Review of technical changes to determine effect upon the quality of articles and the procedures relating to inspection and test thereof

b) Distribution of technical changes to appropriate personnel in an expeditious manner

c) Prompt removal of obsoleted documents, particularly those pertinent to the quality of the product

8.15 PACKAGING AND SHIPPING CONTROL

QA ensures that preservation, packaging, and shipping instructions are issued to shipping inspection. Implementation of these instructions ensures the protection of articles from deterioration, damage, loss, or substitution during storage and shipment. Inspections are also performed to ensure that articles acceptable at the packaging stage are complete and that appropriate documentation is provided when required by contract.

8.16 CUSTOMER SURVEILLANCE REQUIREMENTS

The contractor and his suppliers provide facilities and assistance as may be required by NASA MSC or its designated representatives in performance of their duties, as specified in the contract.

8.17 IDENTIFICATION AND TRACEABILITY CONTROL

Parts and materials procured for use in producing end articles for TAPLE are visually inspected at receipt and checked against a customer-approved critical parts list to ensure that they are properly identified by part and lot number. Subsequent in-process and end-article scheduled inspections include visual verification that assembly parts list records are adequately maintained during all phases of manufacture to ensure:

- Identification of articles and raw materials
- Maintenance of this identification
- Recording of data associated with fabrication, processing, and quality operations

9.0 COSTS

This section contains a Budgetary and Planning cost estimate for a TAPLE system as defined by Volumes I, II, and III of this Final Report. The quantities shown below were verbally agreed to by Mr. W. Zrubek, NASA MSC Project Engineer and Mr. I. G. Gaal, TRW Systems Project Engineer during a telephone conversation on 29 April 1965.

1. One development model (including an SCO demodulator).
2. Two engineering models, one for NASA MSC and one to remain at the contractor's facility.
3. Two prototype models for qualification test, one for subassembly and one for systems qualification test.
4. Three flight assemblies.
5. Three spare flight assemblies.
6. Three SCO demodulators for three MSFN stations.
7. Three EGSE assemblies.

The total estimated cost and fee for the TAPLE systems is presented below. These costs have been identified for the development and the manufacturing, integration, and test phases for each task.

TAPLE FOLLOW-ON PROGRAM

Task	Dollars ($000) Development	Manufacturing, Integration and Test	Total
Project Office	240	320	560
Human Factors	30		30
PCM Encoder	690	1150	1840
DSU	580	500	1080
Transmitter	210	490	700
Antenna	210	250	460
Receiver	230	320	550
Decoder	410	390	800
Signal Conditioner	110	140	250
Power Converter	190	140	330
Diplexer	210	80	290
Cable Harness		50	50
Thermal Control	360	90	450
Housing	40	20	60
TAPLE System	30	810	840
SCO Demodulator	240	220	460
EGSE	440	510	950
Total	4220	5480	9700